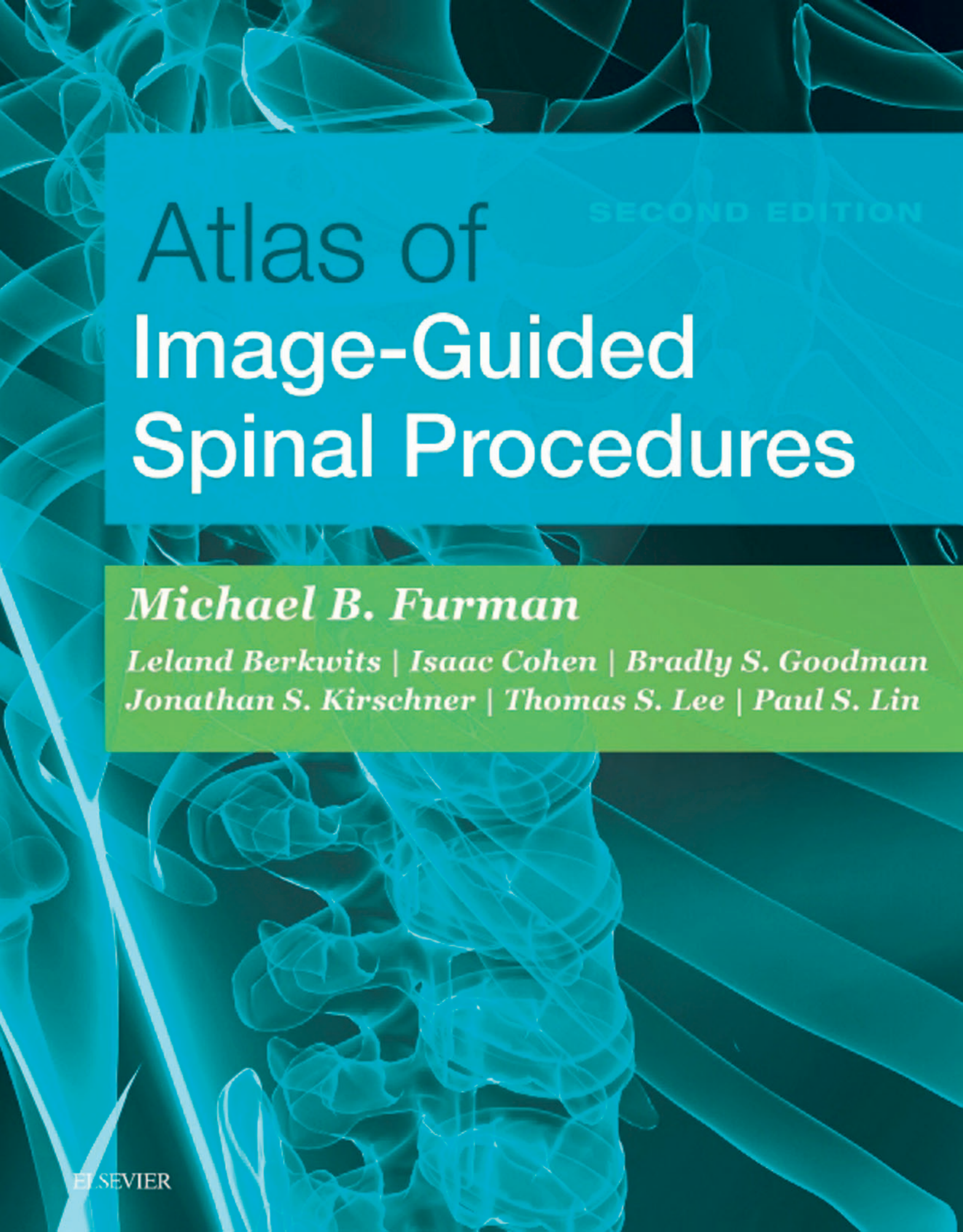
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Atlas of
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Atlas of Image-Guided Spinal Procedures

ANATOMICAL TERMS/ABBREVIATIONS

AA	abdominal aorta
aa joint	atlantoaxial joint
ao joint	atlantooccipital joint
AC	anticoagulant
Acet	acetabulum
Afib	atrial fibrillation
AnPl	antiplatelet
AP	anteroposterior
ArP	z-joint articular pillar
ASA	aspirin
ASIS	anterior superior iliac spine
AVB	anterior vertebral body border
BiTen	biceps tendon
C	cervical
CAP	joint capsule
CCA	common carotid artery
CTJ	costotransverse joint
CLO	contralateral oblique
COX	cyclooxygenase
CP	coracoid process
CVA	cerebrovascular accident
D	dura
DAPT	dual-AP therapy
DES	drug-eluting stent
DR	dorsal ramus
DRG	dorsal root ganglion
DS	digital subtraction
DVT	deep vein thrombosis
E1	first edition
E2	second edition
ESI	epidural steroid injection
FG	fluoroscopic guidance
FH	femoral head
FN	femoral neck
GH	glenohumeral joint
Gmax	gluteus maximus tendon and muscle
Gmed	gluteus medius tendon and muscle
Gmin	gluteus minimus tendon and muscle
GON	greater occipital nerve
GT	greater trochanter
GTB	greater trochanteric bursa
GTPS	greater trochanteric pain syndrome
GV	great vessels
IAP	inferior articular process
IC	iliac crest
ICA	intercostal artery
ICJ	intercoccygeal joint
ICM	intercostal muscles
ICN	intercostal nerve
ICV	intercostal vein
IEP	inferior endplate—we are using the term "endplate" in lieu of ring apophysis
IL	interlaminar
Im Int	image intensifier
INR	international normalized ratio
IP	in-plane
IVC	inferior vena cava
IVD	intervertebral disc
IVF	intervertebral foramen
Jug	jugular vein
Kg	kilogram
L	lumbar
LA	long axis
Lam	lamina
LB	lateral branch of dorsal ramus
LFCN	lateral femoral cutaneous nerve
LH	long head of biceps tendon
LM	lateral masses
LMWH	low molecular weight heparin
LOR	loss of resistance
MAL	mamilloaccesssory ligament
MB	medial branch of dorsal ramus
MBB	medial branch block
mg	milligram
MI	myocardial infarction
mL	milliliter
MOA	mechanism of action
NF	neural foramen
NR	nerve root
NSAID	nonsteroidal antiinflammatory drug
OccArt	occipital artery
OOP	out-of-plane
P	pedicle
PCI	percutaneous coronary intervention
PE	pulmonary embolism
PI	pars interarticularis
PIIS	posterior inferior iliac spine
PL	pleura
PSIS	posterior superior iliac spine
PVB	posterior vertebral body border
RBC	red blood count
RFA	radiofrequency
SA	short axis
SAP	superior articular process
SASDB	subacromial-subdeltoid bursa
SC	spinal cord
SCJ	sacrococcygeal joint
SCS	spinal cord stimulation
SEP	superior endplate—we are using the term "endplate" in lieu of ring apophysis
SG	sympathetic ganglion/chain
SGB	stellate ganglion block
SH	short head of biceps tendon
SI	sacroiliac
SIJ	sacroiliac joint
SN	spinal nerve
SP	spinous process
SSN	suprascapular nerve
STSL	superior transverse scapular ligament
SubScap	subscapularis muscle and tendon

SupraSp	supraspinatus muscle and tendon
Sym	sympathetic chain
T	thoracic
TF	transforaminal
TFESI	transforaminal epidural steroid injection
TFL	tensor fasciae latae
TON	third occipital nerve
TP	transverse process
TRAP	trapezius muscle
TS	thecal sac
TX	treatment
UP	uncinate process
US	ultrasound
USG	ultrasound guidance
V	vascular structure
VA	vertebral artery
VB	vertebral body
VILL	ventral interlaminar line
VN	vagus nerve
VR	ventral ramus
WBC	white blood count
Z-Jt	zygapophysial joint

Radiation Terms (Used only in Chapter 6)

ALARA	as low as reasonably achievable
DAP	dose area product
Gy	gray
HLF	high-level fluoroscopy
KERMA	kinetic energy released per mass of air
kV	kilovolt
mA	milliamp
mrem	millirem
mSv	millisievert
Sv	sievert
XRT	radiotherapy (patient x-ray exposure incurred during the course of medical treatment)

Cervical Levels

C1
C2
C3
C4
C5
C6
C7

Thoracic Levels

T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12

Lumbar Levels

L1
L2
L3
L4
L5

Sacral Levels

S1
S2
S3
S4
S5

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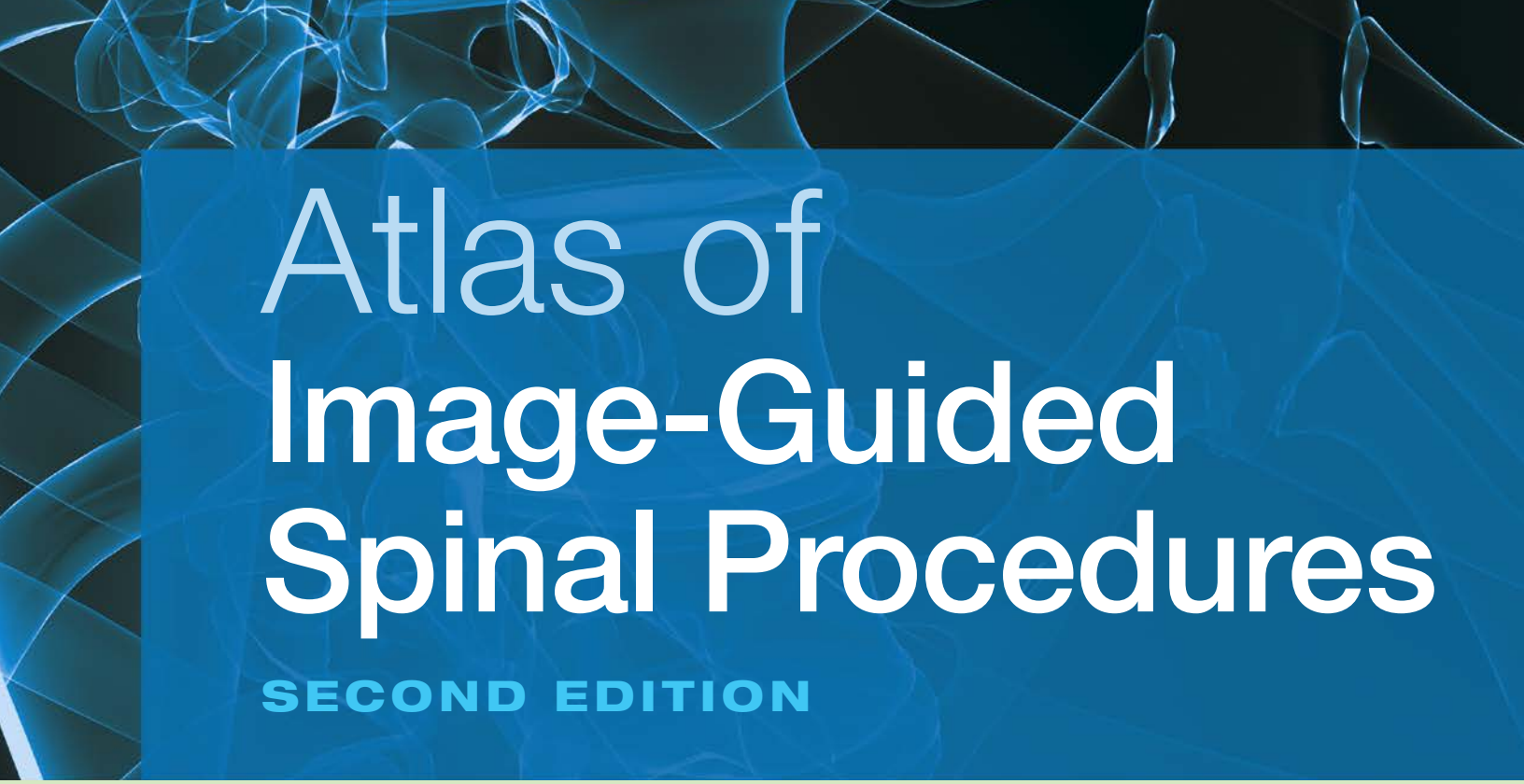

Atlas of Image-Guided Spinal Procedures

SECOND EDITION

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To Esther, Aleeza, Jenna, and Mom, Aida Furman.
In memory of Dad, Willard Furman.
To sisters Laurie and Wendi, Nephew Brian, Niece Krystal, and Great-Nephew Shawn.
You all help make every day beautiful.
-Michael B Furman, MD, MS

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-Leland Berkwits, MD, MS

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-Isaac Cohen, MD

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-Thomas S. Lee, MD

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FOREWORD

It is with great pleasure to introduce the second edition of the *Atlas of Image-Guided Spinal Procedures* by Michael B. Furman, MD, MS, and his associate editors, Leland Berkwits, MD; Isaac Cohen, MD; Jonathan Kirschner, MD; Brad Goodman, MD; Paul Lin, MD; and Thomas Lee, MD. The first edition was a groundbreaking atlas that emphasized appropriate setup for effective and safe interventional spine procedures. This book was universally hailed by the educational community for its ability to transform multifaceted procedures into a series of simpler algorithmic tasks. In offering clarity where only complexity existed, the book rapidly became required reading for anyone learning or teaching interventional spine procedures. Given the unprecedented success of the first edition, the expectations were extraordinarily high for this second edition. Fortunately for the interventional community, this second edition has exceeded every possible expectation.

This second edition naturally improves upon the approach for setting up and performing interventional spine procedures that was pioneered in the first edition. This current atlas offers concise presentations of multiplanar fluoroscopic or ultrasound views to clearly present the ideal setup for spinal procedures. Accompanying these actual images are medical drawings of associated visualized and nonvisualized structures. By combining actual images with medical drawings, the interventionalist gains a deeper understanding of the relevant anatomy. This altas also differentiates itself by presenting both optimal and suboptimal images, thus offering real world usability for providers. Online videos, new sections including procedures for spine pain masqueraders, and enhancements to existing sections on needle techniques, radiation, and patient safety all combine perfectly to result in a truly well-rounded and unique experience.

Even more impressive than these enhancements is that the second edition has accomplished a feat seldom reached by textbooks; it has actually advanced the field of interventional spine medicine. Dr. Furman had the bold insight to include the evolving field of ultrasound medicine. This atlas helps clarify the ultrasound-guided techniques by demonstrating the relevant anatomy and imaging views for safe and effective procedures in similar fluoroscopic presentations. Additionally, this book has tackled the difficult topic of preprocedure anticoagulation/antiplatelet medication. In doing so Dr. Furman has once again offered clarity where only confusion existed. I believe the recommendations in this section will actually become the new standard of care for these procedures and will likely lead to better outcomes for our patients. Because of this foresight, the second edition has evolved from required reading for all trainees to an essential textbook for anyone performing image-guided spine procedures.

Throughout his career Dr. Furman has been a renowned researcher whose publications have helped shape the field. His manuscripts have revolutionized our understanding of contrast flow patterns and refined imaging techniques for axial procedures. He also defined the incidence of vascular uptake and helped demonstrate the relative efficacy of commonly used safety procedures. In addition to his research prowess, he is also the consummate educator. He has given numerous national and international lectures and has directed and taught countless courses for numerous organizations. As a passionate and dedicated teacher, he has taught many fellows how to safely and effectively perform procedures and care for patients. In doing so the number of patients who have been directly and indirectly helped by him is unfathomable.

As a long-time thought leader and pioneer in the field, Dr. Furman has once again advanced the field by the publication of the second edition of the *Atlas of Image-Guided Spinal Procedures*. This book will be invaluable to every person performing these procedures, as well as to our patients. I am honored to call Dr. Furman a friend and colleague.

Thank you for the honor of being part of such a phenomenal book.

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PREFACE TO THE FIRST EDITION

"Every battle is won before it is even fought."
–Sun Tzu, *The Art of War*

THE EVOLUTION OF IMAGE-GUIDED SPINE CARE

Spinal interventions have changed quite a bit since they were done "blindly" without any image guidance. Fluoroscopic visualization is now typically used, and the techniques have evolved from merely using the fluoroscope to "watch" while performing a blind technique. Instead, **we now use fluoroscopic guidance as a tool to efficiently and safely drive the needle tip directly to our desired target while avoiding the unwanted locations.** Instead of gauging depth by "stepping off periosteum," we use true fluoroscopic guidance to visualize the needle tip location relative to specific radio-opaque landmarks. We now use real-time live visualization of contrast instillation. Digital subtraction is becoming more commonplace to identify contrast extent and confirm nonvascular injections. Soon, we may routinely use ultrasound visualization of soft tissue structures to supplement our fluoroscopic visualization (although I must admit ultrasound techniques are not included in *this* atlas edition).

Our atlas presents this *evolved* concept for teaching and learning spinal interventional techniques. I typically teach a procedure by asking, **"Where do you want your needle tip, and how can you get there directly?"** But, equally, if not more important, **"Where *don't* you want your needle tip, and how can you best visualize and avoid those non-targeted or unsafe structures?"** This atlas presents techniques to address these concepts and help answer these and other questions regarding safe and efficient procedural techniques.

SETUP IS KEY

Each procedure is presented similarly using a logical approach, starting with the trajectory view for "setup," appropriate multiplanar fluoroscopic views for safety and accurate needle advancement, and optimal along with suboptimal imaging with and without contrast. For our "setup" view, we purposely avoid presenting *specific* fluoroscopic angles, distances, or "fingerbreadths" and instead focus on each patient's individualized segmental anatomy and associated fluoroscopic imaging to determine each unique trajectory for each procedural level. Fluoroscopic images and accompanying drawings demonstrate both the radiopaque structures you *can* see and the radiolucent structures that you *can't* visualize, yet need to know. **We stress the importance of needle advancement in the *Safety View*.** I strongly encourage you to read our first chapter for further clarification of the concepts and nomenclature used throughout this atlas.

You will note that we have purposely minimized the use of text in this atlas. More important, we want this atlas to serve as a **true image-guided procedural reference** and defer to other textbooks to cover indications, contraindications, or non–image-related features of a given procedure. You will note that I am not referring to you as a "reader." Instead, **I look forward to hearing that you "saw" or "looked at" our atlas.** We are also pleased to present some special chapters on needle techniques, imaging tricks, radiation safety, and L5-S1 disc access, all presented visually, with the same conceptual presentation.

I created this atlas to present concepts that I have honed over my many years of teaching and that fuel my passion. I have learned a lot in the process. There are even more ideas and content that I want to include, but we have to go to press! As an educator, physician, engineer, husband, and father, I have learned that to grow and improve within those roles, **there can always be improvement,** and one must always be open to suggestions. With that in mind, **I encourage you to email me at FurmanSpineAtlas@gmail.com with any suggestions you may have for the next atlas iteration.** If we use your idea, I assure you we will reference you appreciatively. Even if we don't use your suggestion, I look forward to the ongoing dialogue with both new and established colleagues, along with the prospect of learning even more.

Michael B. Furman, MD, MS

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PREFACE TO THE SECOND EDITION

"Every battle is won or lost before it is ever fought."
Sun Tzu – The Art of War

Shu Ha Ri: Learn Fundamentals, Innovate, Transcend.
Traditional Japanese Concept

SETUP IS KEY

Typically, I begin teaching a procedure by asking my fellows, "Where do you want your needle to be, and how can you get it there most efficiently?" I also ask, "Where do you *not* want it to be, and how can you avoid the vital structures that should *not* be encroached?" We developed the *Atlas of Image-Guided Spinal Procedures,* Edition 1 (Atlas E1) to visually demonstrate the answer to these and other fundamental, yet crucial questions.

Atlas E1 focused on utilizing fluoroscopic guidance (FG) as a tool to efficiently and safely drive our needle tips directly to our desired spinal targets while avoiding undesirable locations/structures. Atlas E1presented these fundamentals with a logical, visual, step-by-step approach to safe and efficient procedural planning and execution using the latest image-guidance technology and techniques. Each procedure was presented using the trajectory view for setup. This view is key because a procedure can be performed more safely and efficiently once an intervention's trajectory view has been optimally set up. We presented appropriate multiplanar fluoroscopic views for safe and accurate needle advancement. The safety view demonstrates where the needle tip should not venture and hence its importance for needle advancement. Fluoroscopic images and accompanying drawings illustrated both radiopaque structures seen and radiolucent structures that we cannot visualize, yet need to know. Atlas E1 not only demonstrated optimal performance and contrast patterns but also shared undesirable needle tip locations and suboptimal contrast patterns.

This second edition of the *Atlas of Image Guided Procedures* (Atlas E2) again emphasizes the fundamentals of proper procedural setup, multiplanar and safety views, and optimal and suboptimal imaging. Atlas E2 further improves and innovates on Atlas E1 content by adding and updating more FG content and improving the FG image quality. We have made numerous improvements in the needle technique chapters, fluoroscopic and ultrasound imaging tricks, radiation and patient safety, and L5-S1 disc access, which include new examples, diagrams, and drawings. New reference tables include differentiating optimal from suboptimal epidural contrast flow (Table 12.1) and preprocedural anticoagulation/antiplatelet medication recommendations (Appendix, Tables A1-1A, A1-1B, and A1-2). We also include online access to new videos and additional explanations when static imaging can be supplemented.

THE EVOLUTION OF IMAGE-GUIDED SPINE CARE

Our practices have evolved since Atlas E1 by incorporating new knowledge, technology, and innovations. Many practitioners have integrated ultrasound-guided procedures. The use of ultrasound has facilitated the recognition and treatment of spinal pain "masqueraders" such as head, shoulder, and hip pathology. Atlas E2 thus includes a section devoted to FG and ultrasound-guided (USG) cranial and proximal appendicular procedures. Additionally, USG has also been incorporated to supplement certain fluoroscopic-guided spine procedures, enabling visualization of soft-tissue structures not possible with FG. In Atlas E2, we use a similar presentation for USG procedures incorporating the same "voice" as in our FG procedures using setup views, multiplanar imaging, and safety view and considerations. Ultrasound images and accompanying drawings also demonstrate the relevant structures we can and cannot see, yet need to know.

As in Atlas E1, we have deliberately minimized text. We want this atlas to serve as an image-guided spinal procedural reference and refer readers to other textbooks for indications, contraindications, or non–image-related features for a given procedure. We hope that the *fundamentals* and *innovations* described in this Atlas facilitate you, your practice, and your technique to *transcend* to even higher levels.

As in Atlas E1, I again humbly request that you email me at furmanspineatlas@gmail.com if you have recommendations for future edition improvements.

Thanks and enjoy!

Michael B. Furman, MD, MS

ACKNOWLEDGMENTS

Many talented people have contributed to this atlas. I especially want to thank my associate editors, Lee Berkwits, Isaac Cohen, Brad Goodman, Jonathan Kirschner, Tom Lee, and Paul Lin for assisting with the evolution of this atlas from concept through inception, design, and integration of fluoroscopic and ultrasound techniques.

As a fellow, Tom Lee's procedural drawings helped give me the inspiration that started this process. Lee Berkwits's logical approach helped Tom and me keep the design simple with his suggestions including using fluoroscopic icons and a clear layout. The three of us developed Atlas E1 further as we shared these thoughts with colleagues at AAPM&R workshops and courses. I started "crowd sourcing" the review process. Brad Goodman offered invaluable reviews for Atlas E1. He was our most prolific Atlas E1 reviewer. His diligent and continuous input made him an obvious asset to have as an Atlas E2 assistant editor.

After Atlas E1 published, Isaac Cohen responded to the request in my E1 preface and sent me many constructive suggestions. We instantly became friends and colleagues, and he continues his hard work and attention to detail as an Atlas E2 assistant editor. Jon Kirschner was a fellow and author during the initial Atlas E1 creation. He has evolved into an academic and ultrasound powerhouse, has already co-edited an ultrasound atlas within a year of finishing his fellowship, and has already become the Hospital for Special Surgery's Spine and Sports Fellowship Director. We were fortunate to get him on our E2 team. Paul Lin is a past fellow and current partner whose procedural and US skills are intuitive and logical, and he has truly transcended in his abilities. He has contributed significantly to the E2 US content. I cannot thank these six colleagues enough for their dedication to this project.

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I want to also thank the editorial staff and artists at Elsevier and Dartmouth Publishing, Inc., who have helped bring this atlas from concept to fruition through the MANY years and helped us to create a unique product: Rolla Couchman, Delores Meloni, Elena Pushaw, Ceil Nuyianes, Stephanie Davidson, Laura Gallagher, Victoria Helm, Mike Carcel, Don Scholz, Dan Pepper, Grace Onderlinde (Graphic World), Kristine Feeherty, Steven Stave, Jessica Pritchard, Kayla Wolfe, and especially Sharon Corell and Ann Anderson.

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With sincerest gratitude,

Michael B. Furman, MD, MS

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EDITOR BIOGRAPHY

Michael B. Furman, MD, MS, was born and raised in Scranton, PA. He earned a BSE and MS in chemical engineering respectively from the University of Pennsylvania in 1982 and Cornell University in 1986. He received his MD from Temple University in 1990 and finished his internship at York Hospital in 1991 and his residency training in physical medicine and rehabilitation at Temple University Hospital in 1994. He completed his interventional pain fellowship at Georgia Pain Physicians (formerly Georgia Spine and Sport Physicians) in 1995. He has been in private practice since 1995 with OSS Health, PC, in York, Pennsylvania, a multidisciplinary musculoskeletal group.

Dr. Furman is board certified in physical medicine and rehabilitation with ACGME subspecialization in pain medicine and sports medicine. He is the founder and director of the Interventional Spine and Sports Fellowship at OSS Health in York, Pennsylvania. He has trained more than 70 sports and interventional spine fellows. He has been a course director or instructor at numerous AAPM&R, PASSOR, SIS, and NASS courses and workshops. Dr. Furman's area of special interest is the diagnosis and treatment of spinal disorders, musculoskeletal injuries, and other painful conditions. He is recognized as a thought leader and educator and has won numerous awards for his teaching, service, and clinical care, including the PASSOR Distinguished Clinician Award, the AAPM&R Musculoskeletal Council Service Award, and the Richard and Hinda Rosenthal Foundation Lectureship Award.

Dr. Furman's passion is teaching various subjects, including spine care, safe and efficient application of spinal technology, billing/coding, risk management, and ways to make every day "a beautiful day." He teaches these and other related topics internationally and locally using numerous original research publications and book chapters. He has served on numerous AAPM&R, NASS, PASSOR, and SIS committees and task forces, including nonoperative treatments, research, medical education, clinical guidelines, maintenance of certification, credentialing, billing/coding, socio-economics, finance, and by-laws. He was chair of the AAPM&R Resident Physician Council from 1992 to1993 and has served on the PASSOR Board of Governors and the AAPM&R Board of Governors.

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Dr. Furman lives in York, Pennsylvania, where he enjoys many outdoor activities, with his wife, Esther, daughters, Aleeza and Jenna, and numerous pets.

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CHAPTER 1

Introduction: How to Use This Atlas

Jonathan S. Kirschner, Michael B. Furman, and Leland Berkwits

Interventional procedures play an integral role in the diagnosis and treatment of spinal pain. Injections can also be helpful in diagnosing or ruling out conditions that commonly masquerade as spinal pain, such as hip or shoulder pathology. Practitioners from multiple specialties perform these procedures with great variability in procedural technique and training. This atlas should function as a reference tool for providing a safe, structured approach to performing image-guided interventional procedures used to diagnose and treat symptoms emanating from the spine and/or structures that may masquerade as spinal conditions. This atlas is intended to be an adjunct to formal training in image-guided interventional pain care; it is not meant to be used in lieu of proper hands-on training with experienced mentors.

Our first edition of this atlas focused primarily on fluoroscopic procedures. In this second edition, we again incorporate fluoroscopic techniques. However, we also demonstrate commonly performed ultrasound-guided procedures. We emphasize hybrid procedural techniques, employing a combination of ultrasound and fluoroscopic guidance. Combining both modalities can result in reduced radiation exposure and improved soft tissue visualization in high-risk neurovascular areas, with the benefits of real-time contrast enhancement for confirmation.

BOOK FORMAT

Chapters are color coded according to the body region, with colors along the book's edge for easy reference. In the table of contents, the ultrasound chapter listings are distinguished from the fluoroscopy chapter listings.

The atlas starts with introductory chapters, including needle techniques, fluoroscopic and ultrasound pearls, and patient and radiation safety. The procedural techniques are arranged from the typically safer lumbosacral region procedures to the more complex cervical and atlanto-occipital region procedures. A bonus section on fluoroscopic- and/or ultrasound-guided injection techniques used to address structures that masquerade as spinal conditions is included toward the end of the book.

A final appendix of reference tables has also been included, with an antiplatelet/anticoagulant discussion, a steroid equivalency table, a local anesthetic dose reference guide, an intrathecal contrast and dose reference, and suggestions for premedication for those with a history of contrast reactions. These tables are provided as a handy reference guide but may be subject to change as new studies and guidelines are published. While every attempt was made to provide evidence-based recommendations, each patient situation should be weighed individually.

This introductory chapter will assist the reader in making the most of this atlas. Image-guided interventional procedures can be performed more efficiently, accurately, and safely with consistent application of disciplined principles and consistent algorithmic methodology.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

For each procedure, we provide relevant fluoroscopic and/or ultrasound images with anatomic diagrams and photographs for appropriate landmark identification. A consistent set of procedural views throughout the atlas is denoted by the icons shown below. The "setup" for each technique is demonstrated. Multiplanar imaging will also be emphasized. Ideal needle positioning before contrast injection, optimal and suboptimal contrast flow patterns (under fluoroscopy), and needle positions are shown. Most importantly, safety issues, anatomic concerns, common pitfalls, and "pearls" are highlighted.

Individual or combined introductions for each chapter, or set of chapters, are provided with associated bibliographies and references.

The list of collective anatomic terms/abbreviations is provided in the front matter of this atlas.

FLUOROSCOPIC VIEWS

Trajectory View: “Setup Is Key”

The fluoroscopic trajectory view, which is also known as the *hubogram, hub view, needle view, “down-the-barrel,”* or *coaxial view,* provides the initial orientation for needle placement and advancement. Because proper setup is so imperative, we cannot overemphasize this view’s importance. In this view, the interventionalist directly visualizes the needle’s path to the final target. Instead of estimating the needle’s trajectory, an unobstructed needle pathway is visualized, and an associated needle entry point is identified (Fig. 1.1). An initial trajectory view can be identified

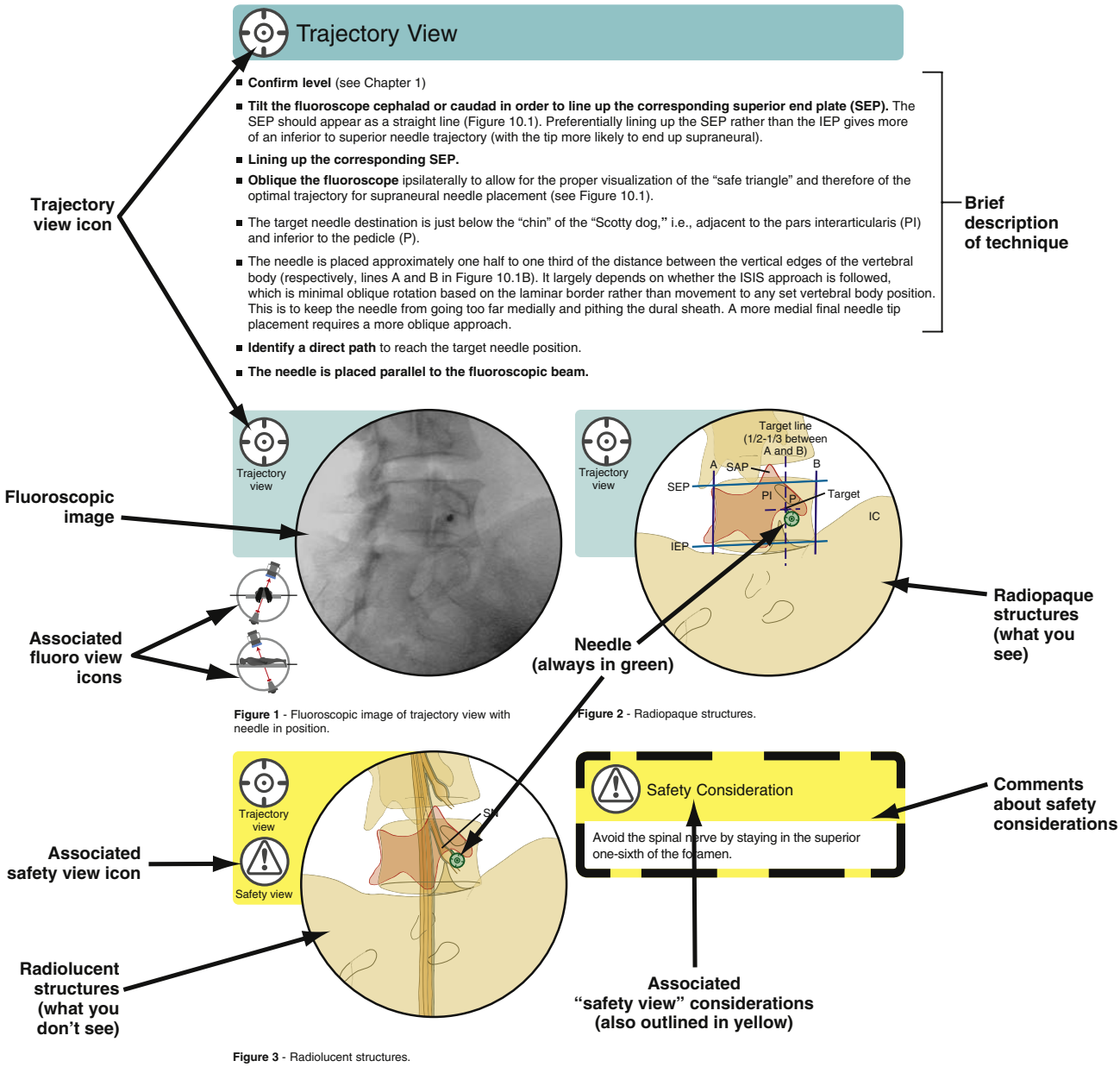
Trajectory View
Confirm level (see Chapter 1)
Tilt the fluoroscope cephalad or caudad in order to line up the corresponding superior end plate (SEP). The SEP should appear as a straight line (Figure 10.1). Preferentially lining up the SEP rather than the IEP gives more of an inferior to superior needle trajectory (with the tip more likely to end up supraneural).
Lining up the corresponding SEP.
Oblique the fluoroscope ipsilaterally to allow for the proper visualization of the “safe triangle” and therefore of the optimal trajectory for supraneural needle placement (see Figure 10.1).
The target needle destination is just below the “chin” of the “Scotty dog,” i.e., adjacent to the pars interarticularis (PI) and inferior to the pedicle (P).
The needle is placed approximately one half to one third of the distance between the vertical edges of the vertebral body (respectively, lines A and B in Figure 10.1B). It largely depends on whether the ISIS approach is followed, which is minimal oblique rotation based on the laminar border rather than movement to any set vertebral body position. This is to keep the needle from going too far medially and pithing the dural sheath. A more medial final needle tip placement requires a more oblique approach.
Identify a direct path to reach the target needle position.
The needle is placed parallel to the fluoroscopic beam.
Trajectory view icon
Brief description of technique
Trajectory view
Fluoroscopic image
Associated fluoro view icons
Figure 1 - Fluoroscopic image of trajectory view with needle in position.
Target line (1/2-1/3 between A and B)
A
SAP
B
SEP
PI
P
Target
IC
IEP
Needle (always in green)
Radiopaque structures (what you see)
Figure 2 - Radiopaque structures.
Trajectory view
Safety view
SN
Associated safety view icon
Radiolucent structures (what you don’t see)
Safety Consideration
Avoid the spinal nerve by staying in the superior one-sixth of the foramen.
Comments about safety considerations
Associated “safety view” considerations (also outlined in yellow)
Figure 3 - Radiolucent structures.

Fig. 1.1. A sample page that demonstrates the fluoroscopic trajectory view; note the Trajectory View icons. The trajectory view provides the initial orientation for needle placement and advancement for almost all fluoroscopic procedures found in this atlas. Note how the fluoroscopic image (*top left*), radiopaque (*top right*), and radiolucent structures (*bottom left*) are shown for most figures in this atlas. When there is a safety view, it is outlined with a yellow banner, and the safety considerations are listed. In particular, radiolucent structures that should be avoided are shown and described. Note that we typically label the associated drawing and not the fluoroscopic image.

for almost all procedures found in this atlas. The trajectory view is typically used only for initial setup and needle placement. On occasion, the trajectory view can also be one of the final multiplanar views and will be so indicated.

The setup is obtained by appropriately positioning the fluoroscope relative to the patient. The fluoroscopic image produced using this C-arm position will be depicted via the Trajectory View icon. The ease and timeliness of a procedure will be heavily dependent on an appropriate trajectory view setup.

For most trajectory and multiplanar fluoroscopic images found in this atlas, a similar format will be used. The top left picture will be the actual fluoroscopic image. To the right, a drawing with radiopaque structures (that you can see) is outlined and labeled. At the bottom, a drawing with radiolucent structures (that you cannot see) is outlined and labeled. The needle and hub are green in all atlas drawings. When there is a "safety view," the safety considerations are listed. In particular, lucent structures that should be avoided are shown and described.

In the trajectory view, the needle is placed parallel to the direction of the fluoroscopic beam (i.e., perpendicular to the image intensifier's surface), and a coaxial image of the needle is obtained (Fig. 1.2). On initial placement, the needle should be advanced just deep enough so that it takes sufficient hold (i.e., purchase) in the soft tissues to remain in a stable position. A "hubogram" should be obtained early, *before significantly advancing the needle along its trajectory*. As intermittent fluoroscopic imaging confirms the needle advancement parallel to the fluoroscope beam, minor trajectory adjustments are made to maintain the needle shaft parallel to the X-ray beam.

In most cases, the hub view is only used to identify the needle starting point and trajectory angle relative to the patient. After the needle is advanced sufficiently to stay along its intended trajectory, additional multiplanar views are used for further advancement, as described later in this chapter. **Occasionally, the trajectory view is also one of the final multiplanar views.** For example, the lumbar zygapophyseal joint nerve block target (i.e., the "eye or eyebrow of the Scotty dog") can be visualized on the oblique trajectory view. For most other procedures (e.g., the lumbar transforaminal epidural), the trajectory view is not used as one of the final multiplanar views.

Fig. 1.2. To effectively use the trajectory view, the needle is placed parallel to the direction of the fluoroscopic beam (i.e., perpendicular to the image intensifier's surface, the pink line simulated here), and a coaxial image of the needle is obtained. Static pictures are taken, and minor adjustments can still be made to keep the needle parallel to the X-ray beam.

Multiplanar Views

When the needle tip is perceived to be close to its target, a minimum of two (multiplanar) views is necessary to confirm its position. Only by obtaining two or more views can the needle tip position be accurately triangulated. It is important to confirm the needle tip position prior to contrast instillation to avoid obscuring the image and/or potential harm. Although the final views are typically the anteroposterior and lateral views, there are some procedures with other recommended multiplanar views (i.e., oblique) that we recommend for needle tip position and/or contrast confirmation. This will be described in the respective chapters.

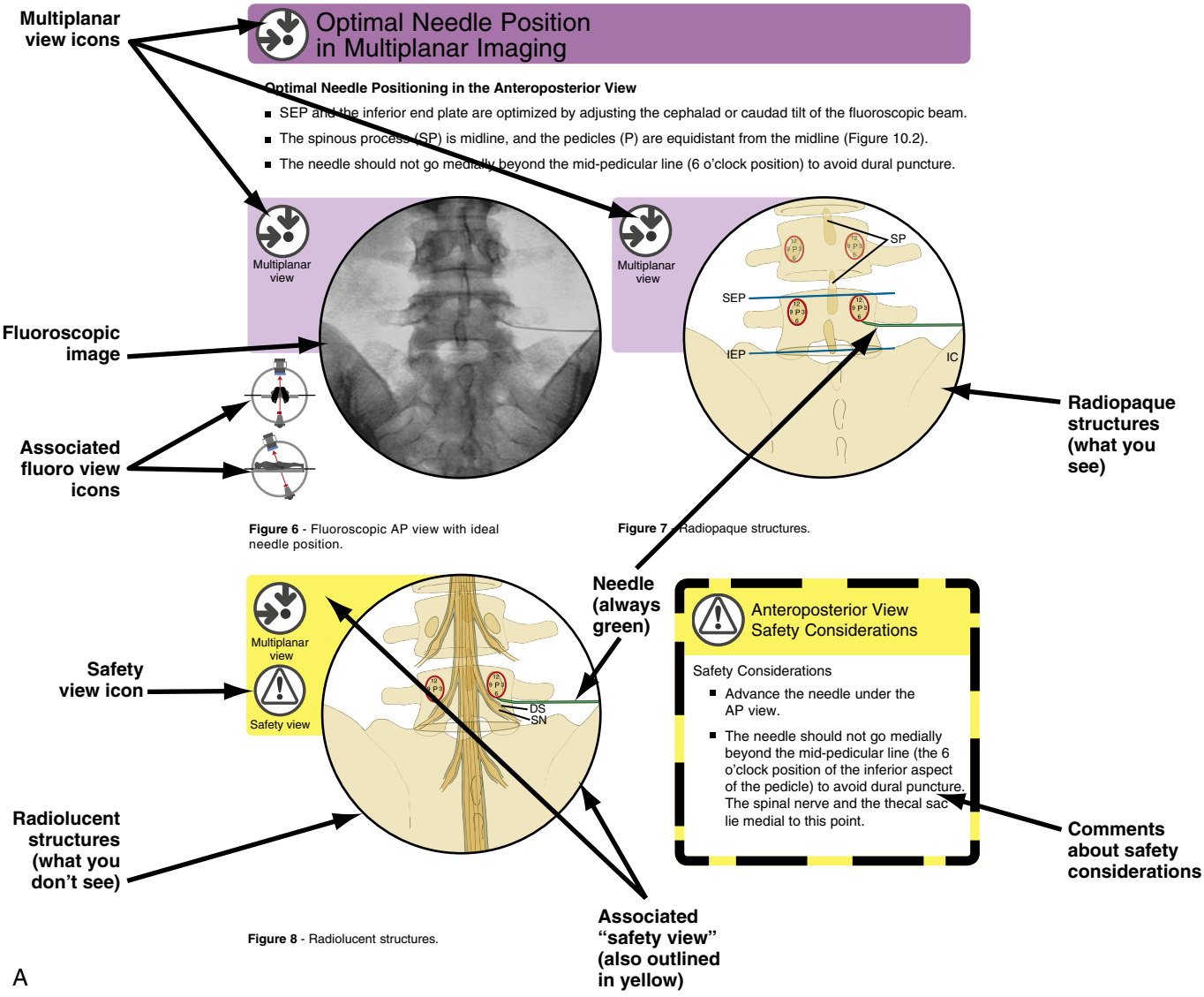
Multiplanar view icons
Optimal Needle Position in Multiplanar Imaging
Optimal Needle Positioning in the Anteroposterior View
SEP and the inferior end plate are optimized by adjusting the cephalad or caudad tilt of the fluoroscopic beam.
The spinous process (SP) is midline, and the pedicles (P) are equidistant from the midline (Figure 10.2).
The needle should not go medially beyond the mid-pedicular line (6 o'clock position) to avoid dural puncture.
Multiplanar view
Fluoroscopic image
Associated fluoro view icons
Figure 6 - Fluoroscopic AP view with ideal needle position.
Multiplanar view
SP
SEP
IEP
IC
Radiopaque structures (what you see)
Figure 7 - Radiopaque structures.
Needle (always green)
Safety view icon
Multiplanar view
Safety view
DS
SN
Anteroposterior View Safety Considerations
Safety Considerations
Advance the needle under the AP view.
The needle should not go medially beyond the mid-pedicular line (the 6 o'clock position of the inferior aspect of the pedicle) to avoid dural puncture. The spinal nerve and the thecal sac lie medial to this point.
Comments about safety considerations
Radiolucent structures (what you don't see)
Figure 8 - Radiolucent structures.
Associated "safety view" (also outlined in yellow)
A

Fig. 1.3. A and B, Sample pages that demonstrate multiplanar views (anteroposterior and lateral). Note the Multiplanar View icons. In this atlas, the multiplanar views demonstrate at least two views with ideal needle placement. As per the usual convention used in this atlas, the top left picture is the actual fluoroscopic image. To the right, the drawing with opaque structures (that you can see) is outlined and labeled. At the bottom, the drawing with radiolucent structures (that you cannot see) is outlined and labeled. The needle and hub are green. When there is a safety view, it is shown with a yellow banner outline, the safety considerations are listed, and the Safety View icon is depicted.

Safety Considerations

To successfully perform a procedure, the needle tip must reach its intended target. Additionally—and of equal or greater importance—**the safety view ensures that the needle tip does *not* go where it should *not* be**.

Interventional pain practitioners should know the key structures to avoid during each procedure (e.g., nerve tissue, blood vessels, and viscera) as well as the best way to visualize them. Unfortunately, fluoroscopy, unlike ultrasound, does not allow for the direct visualization of soft tissue. Because most of these radiolucent structures cannot be directly visualized, the associated radiopaque landmarks need to be optimally visualized. "Safety view" is the projection that best visualizes the radiopaque fluoroscopic landmarks that correspond with radiolucent structures we are trying to avoid. For each procedure, this atlas will include a separate Safety Considerations box that identifies safety considerations and their relevant radiolucent structures (Figs. 1.1 and 1.3).

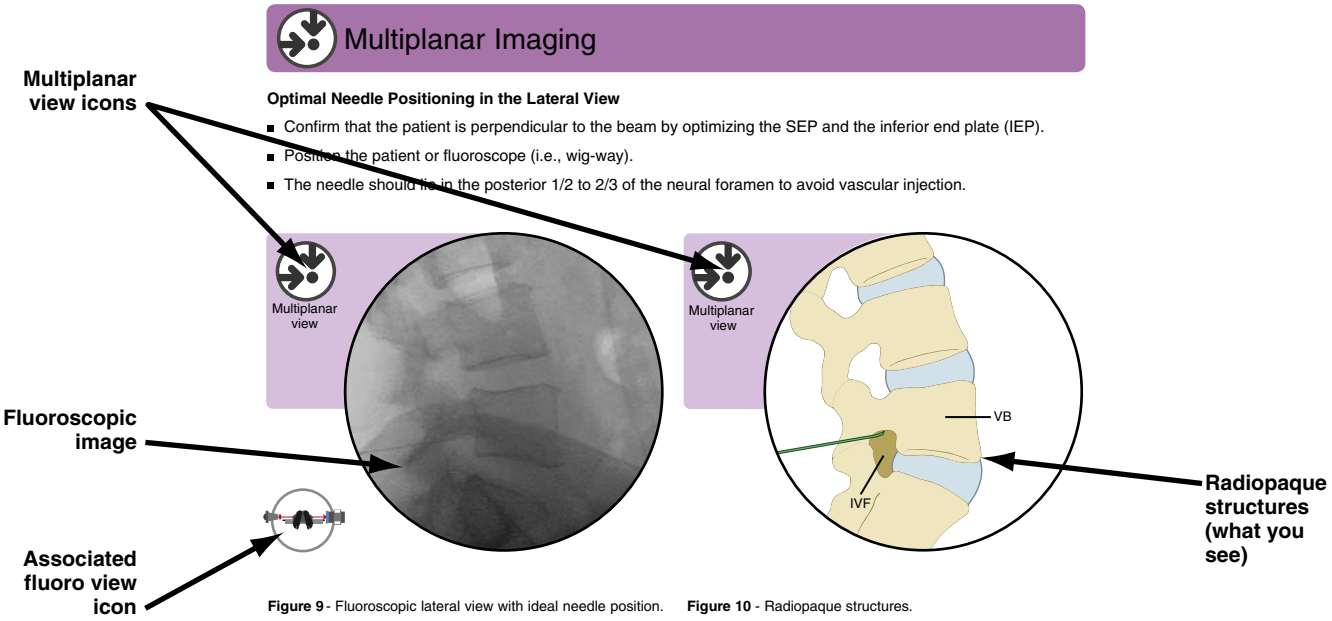
Multiplanar Imaging
Multiplanar view icons
Optimal Needle Positioning in the Lateral View
Confirm that the patient is perpendicular to the beam by optimizing the SEP and the inferior end plate (IEP).
Position the patient or fluoroscope (i.e., wig-way).
The needle should lie in the posterior 1/2 to 2/3 of the neural foramen to avoid vascular injection.
Multiplanar view
Multiplanar view
Fluoroscopic image
Associated fluoro view icon
VB
IVF
Radiopaque structures (what you see)

Figure 9 - Fluoroscopic lateral view with ideal needle position.

Figure 10 - Radiopaque structures.

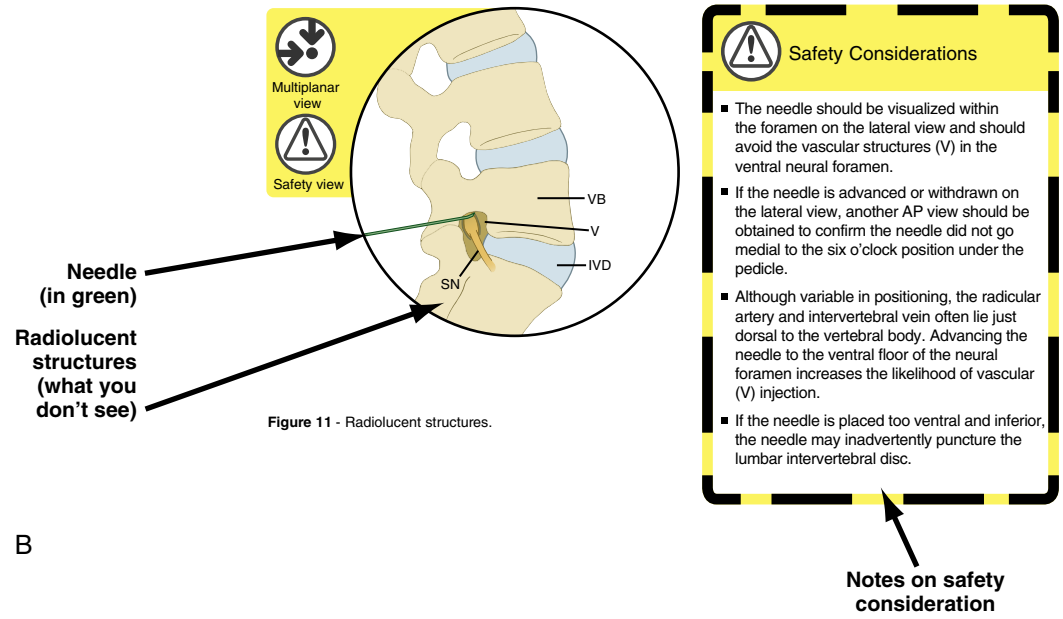
Multiplanar view
Safety view
VB
V
IVD
SN
Needle (in green)
Radiolucent structures (what you don't see)
Safety Considerations
The needle should be visualized within the foramen on the lateral view and should avoid the vascular structures (V) in the ventral neural foramen.
If the needle is advanced or withdrawn on the lateral view, another AP view should be obtained to confirm the needle did not go medial to the six o'clock position under the pedicle.
Although variable in positioning, the radicular artery and intervertebral vein often lie just dorsal to the vertebral body. Advancing the needle to the ventral floor of the neural foramen increases the likelihood of vascular (V) injection.
If the needle is placed too ventral and inferior, the needle may inadvertently puncture the lumbar intervertebral disc.
Notes on safety consideration

Figure 11 - Radiolucent structures.

B

Fig. 1.3, cont'd

Optimal Image (Fig. 1.4)

Optimal needle placement and/or contrast flow patterns are demonstrated for almost all procedures.

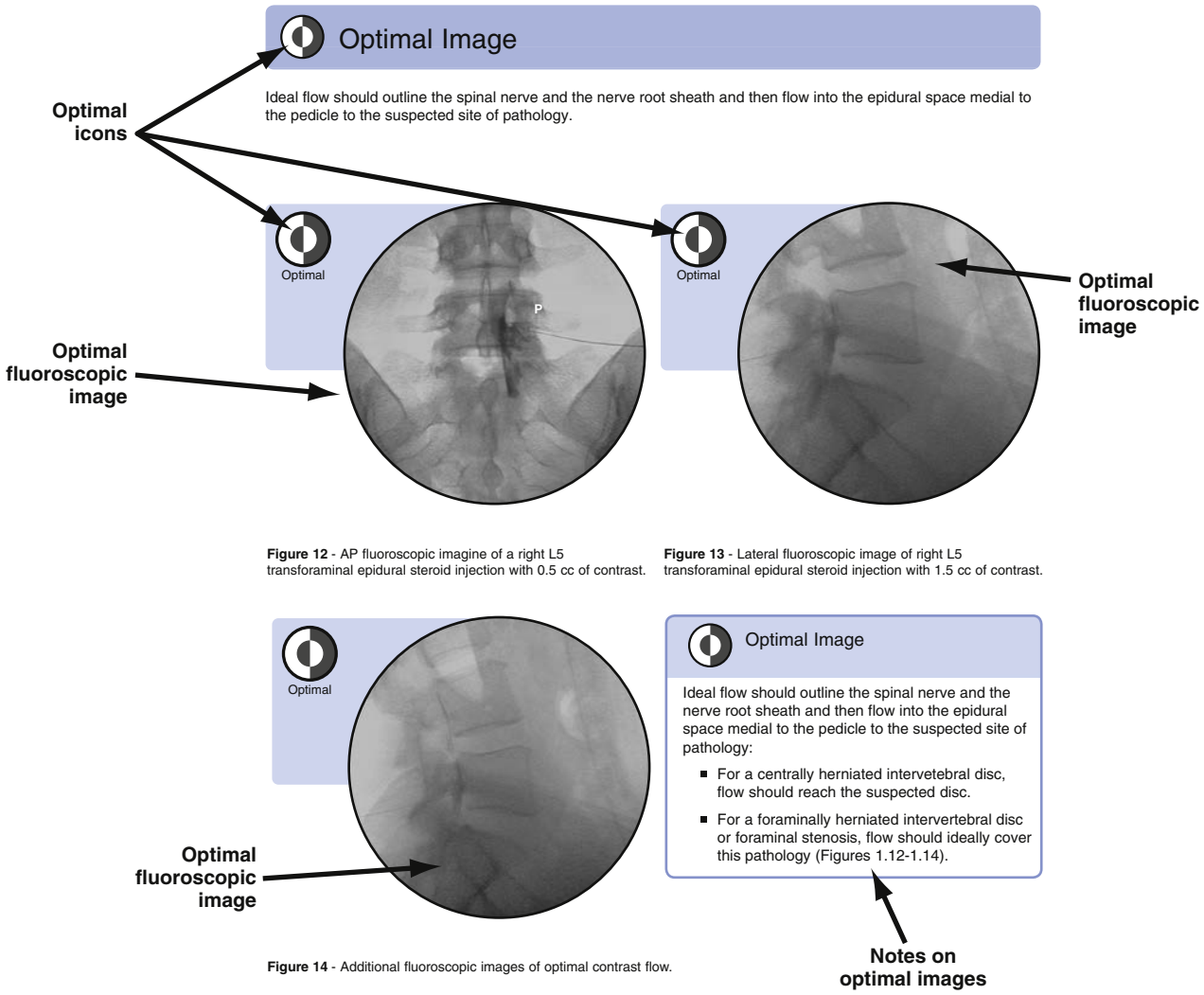
Optimal Image
Ideal flow should outline the spinal nerve and the nerve root sheath and then flow into the epidural space medial to the pedicle to the suspected site of pathology.
Optimal icons
Optimal
Optimal
Optimal fluoroscopic image
Optimal fluoroscopic image
Optimal
Optimal Image
Ideal flow should outline the spinal nerve and the nerve root sheath and then flow into the epidural space medial to the pedicle to the suspected site of pathology:
For a centrally herniated intervetebral disc, flow should reach the suspected disc.
For a foraminally herniated intervertebral disc or foraminal stenosis, flow should ideally cover this pathology (Figures 1.12-1.14).
Optimal fluoroscopic image
Notes on optimal images

Figure 12 - AP fluoroscopic imagine of a right L5 transforaminal epidural steroid injection with 0.5 cc of contrast.

Figure 13 - Lateral fluoroscopic image of right L5 transforaminal epidural steroid injection with 1.5 cc of contrast.

Figure 14 - Additional fluoroscopic images of optimal contrast flow.

Fig. 1.4. For each procedure, ideal needle placement and/or contrast flow patterns will be demonstrated, with associated icons and notes.

Suboptimal Image (Fig. 1.5)

Suboptimal contrast flow patterns (e.g., muscular, vascular) are demonstrated for many procedures. When appropriate, this atlas will also demonstrate how needle adjustments can change a suboptimal injection into an optimal one.

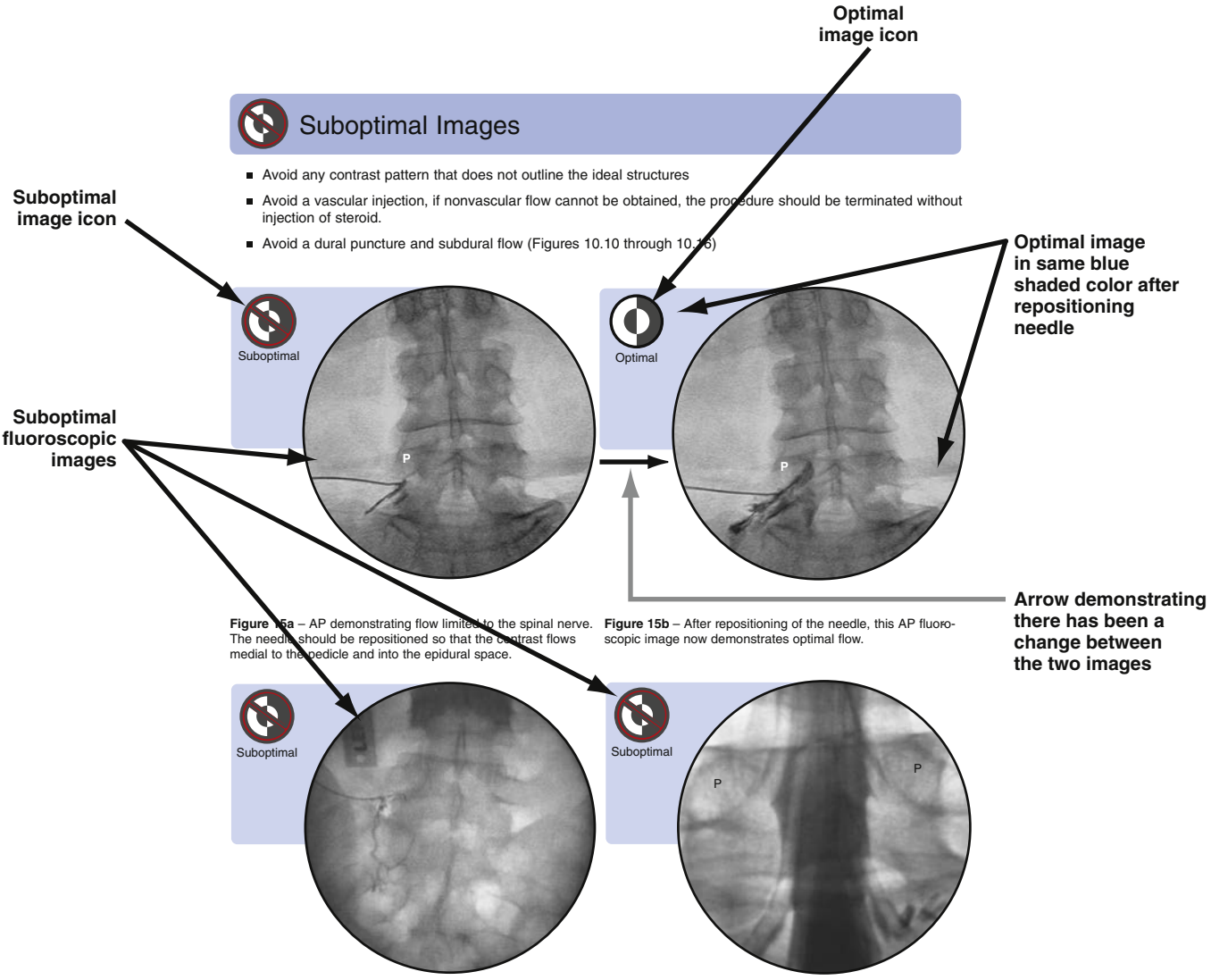
Optimal image icon
Suboptimal Images
Avoid any contrast pattern that does not outline the ideal structures
Avoid a vascular injection, if nonvascular flow cannot be obtained, the procedure should be terminated without injection of steroid.
Avoid a dural puncture and subdural flow (Figures 10.10 through 10.16)
Suboptimal image icon
Optimal image in same blue shaded color after repositioning needle
Suboptimal
Optimal
Suboptimal fluoroscopic images
P
P
Arrow demonstrating there has been a change between the two images
Suboptimal
Suboptimal
P
P

Figure 15a – AP demonstrating flow limited to the spinal nerve. The needle should be repositioned so that the contrast flows medial to the pedicle and into the epidural space.

Figure 15b – After repositioning of the needle, this AP fluoroscopic image now demonstrates optimal flow.

Figure 16 – The fluoroscopic image above demonstrates vascular flow. Although the image above is static, when observed under live fluoroscopy, the contrast rapidly dissipates.

Figure 17 – Myelogram: This demonstrates subdural flow; injecting any futher medication should be avoided at this level.

Fig. 1.5. Sample page with suboptimal images. Note the suboptimal icon that accompanies the images. After the top left suboptimal contrast pattern was obtained, the needle was readjusted to obtain the optimal flow pattern shown on the top right image; the improved picture with correct needle position has an associated Optimal icon. The bottom two suboptimal images have an associated suboptimal icon.

Fluoroscopic Angle Icons

As described previously, icons will be used to represent the trajectory, multiplanar (i.e., precontrast), and safety views as well as the optimal and suboptimal images.

Icons representing the fluoroscopic angles used to obtain images displayed in the text are paired with each fluoroscopic image. The icons provide a quick visual reference of approximate fluoroscopic tilt and oblique angles, as well as patient positioning, in multiple planes. The convention used is one in which the upright C-arm is 0 degrees oblique and 0 degrees tilt. Likewise, the lateral projection will be at 90 degrees oblique. Figs. 1.6 to 1.9 show a fluoroscope relative to a simulated prone patient and the corresponding tilt and oblique icons. Figs. 1.10 and 1.11 show a fluoroscope relative to a simulated supine patient and the corresponding tilt and oblique icons. Some of the Chapter 30 (cervical

Fig. 1.6. A, A simulated patient in a prone position with 0 degrees oblique and the associated icon. **B,** A simulated patient in a prone position with 0 degrees tilt and the associated icon.

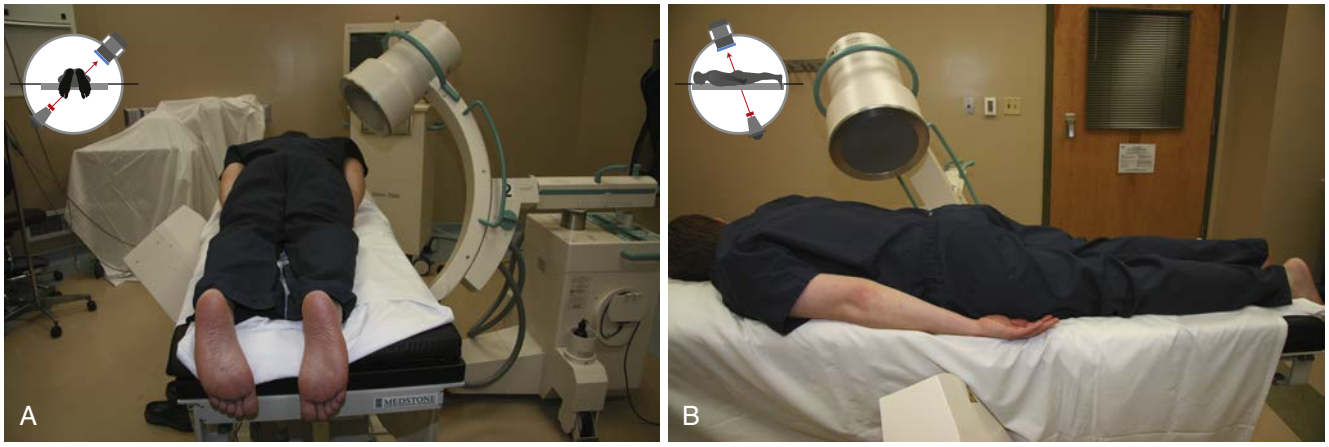

Fig. 1.7. A and B, The fluoroscope is obliqued right and tilted cephalad. **A,** The fluoroscope is at 45 degrees right oblique, with the associated icon and **B,** is at 20 degrees cephalad tilt, with the associated icon.

Fig. 1.8. A and B, A simulated patient with the fluoroscope in a lateral position (i.e., 90 degrees oblique). With the simulated patient in true lateral, the 90-degree icon is used; a tilt icon will typically not be included.

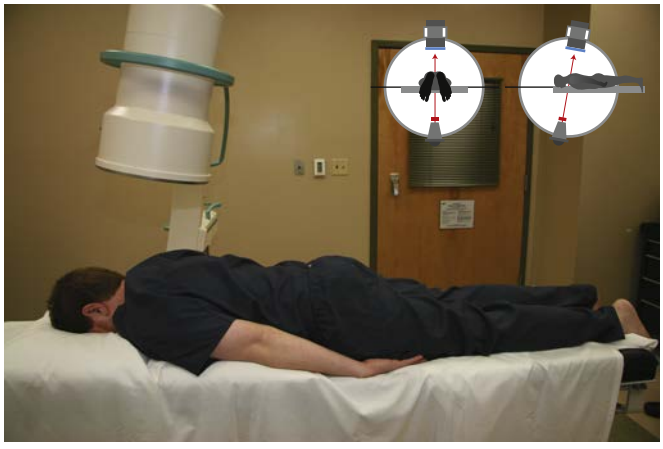

Fig. 1.9. A simulated prone patient in position with 0 degrees oblique and a slight caudad tilt and the associated icons.

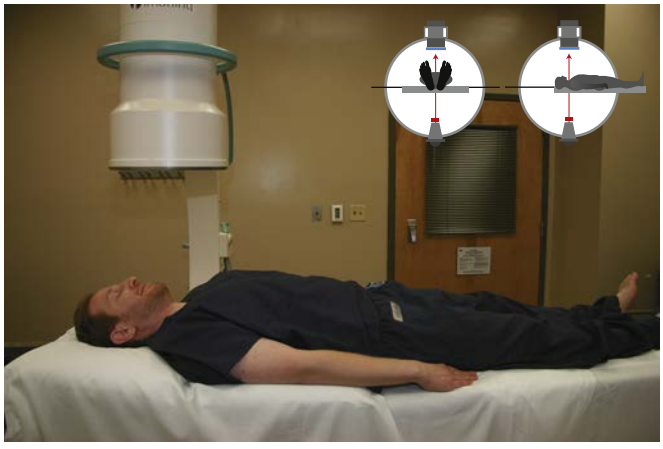

Fig. 1.10. A simulated supine patient, posteroanterior view, in position with 0 degrees oblique and 0 degrees tilt and the associated icons.

Fig. 1.11. A simulated supine patient, posteroanterior view, in position with about 40 degrees left oblique and slight caudad tilt and the associated icons.

Z-joint) procedures are performed in a side-lying position (not shown here in Chapter 1) and have similar icons depicting the fluoroscope position relative to the patient. Because definitive angles are rarely used to set up trajectories, this atlas will only include drawings with approximate angles to orient the reader; the actual angles are deliberately not reported because they vary greatly by patient and by spinal segmental levels. Instead, we recommend focusing more on the "look" of the image and less on actual angles. Mastery of this comes with sufficient procedural volume in a proper training environment.

For the procedures that are performed with the patient in a supine position (e.g., cervical discography, stellate ganglion block), appropriate supine icons will be used. Note that in the supine position, the patient's right is on the left of the fluoroscopic image and vice versa.

ULTRASOUND VIEWS

For ultrasound procedures demonstrated in this atlas, there is no "trajectory" view analogous to fluoroscopic procedures. When available, we still recommend multiplanar/confirmatory imaging using both in-plane (IP) and out-of-plane (OOP) views. The relevant sonoanatomy will be demonstrated, as well as pictures for proper transducer placement and room setup. We recommend the practitioner be positioned directly across from the ultrasound unit, with the patient positioned between the practitioner and the ultrasound device. This setup will facilitate needle entry point visualization relative to the patient's surface anatomy, optimize transducer position relative to the patient and needle, and enable ideal screen visualization.

Safety, multiplanar, optimal, and suboptimal views and icons will be shown, similar to the fluoroscopy chapters.

Linear/Curvilinear Transducer Icons

Icons will denote which transducer (linear or curvilinear) or orientation (IP or OOP) is being used to perform a given procedure. A hockey stick transducer may be substituted for superficial procedures instead of a linear transducer, but is not demonstrated in any images/procedures in this atlas; therefore, no hockey stick icon is depicted.

In-Plane Icons (Linear and Curvilinear)

Ultrasound-guided procedures can be described by how the transducer is positioned relative to the orientation of the structure of interest (long axis or short axis) or relative to how the needle is visualized (IP or OOP). Further nuances and details are provided in Chapter 4, Ultrasound Techniques and Pearls.

An IP approach aligns the plane of the thin slice of anatomy imaged by the ultrasound beam parallel to the shaft of the needle, thus, visualizing the full needle trajectory, including the needle tip and surrounding soft tissues. IP approach can serve as an ideal starting view because the entire needle can be seen along its path. An IP icon using either a linear or curvilinear transducer will accompany the associated ultrasound images.

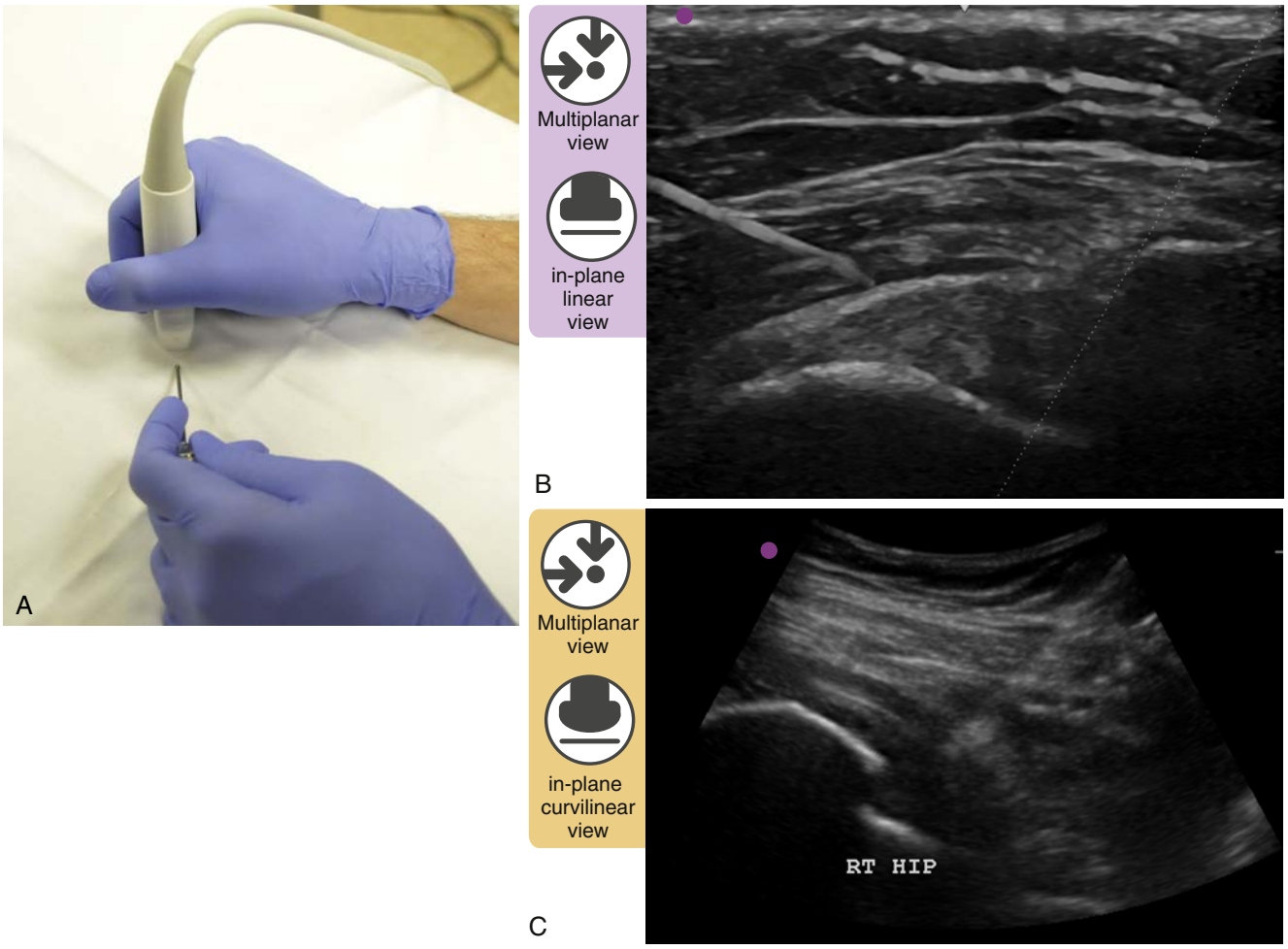

Fig. 1.12. A, Simulated in-plane needle placement with the needle parallel to the linear transducer orientation. **B,** Example of subacromial/subdeltoid injection using a linear transducer with IP needle placement with accompanying icon. **C,** Example of hip injection using a curvilinear transducer with IP needle placement with accompanying icon. The multiplanar icon is also shown since there are additional OOP confirmatory views associated with these images.

Out-of-Plane Icons (Linear and Curvilinear)

An OOP view shows the needle in cross section. The needle appears as a dot, and its tip cannot be directly visualized. An OOP view is most often used as a confirmatory/multiplanar view, used after the corresponding IP view has been used for the majority of needle advancement. The soft tissues visualized in the OOP view provide additional safety information. An OOP icon using either a linear or curvilinear transducer will accompany the associated ultrasound images.

Although we typically present the initial needle placement with an IP technique, we will occasionally present ones that start with OOP imaging, utilizing an IP/multiplanar confirmation (e.g., see Chapter 30C, Cervical Zygapophysial Joint Nerve (Medial Branch) Injection—Anterolateral Approach: Ultrasound Guidance).

Figs. 1.12 to 1.17 demonstrate sample pages and transducer icons used in this atlas. We typically present four frames for ultrasound-guided procedures. The top left is the ultrasound image (Figure A). The top right is a drawing (Figure B) representing the corresponding structures seen in Figure A. We will often use a yellow outline to depict the anatomic region visualized by the ultrasound beam. The bottom left picture (Figure C) demonstrates where the ultrasound transducer is placed relative to the patient. A rectangle is used to represent the transducer over the body region. A purple dot is used to indicate the transducer side that will be on the screen's left side. The picture on the bottom right (Figure D) will typically represent the room setup.

As with the fluoroscopic techniques, optimal and suboptimal imaging will be demonstrated with associated icons.

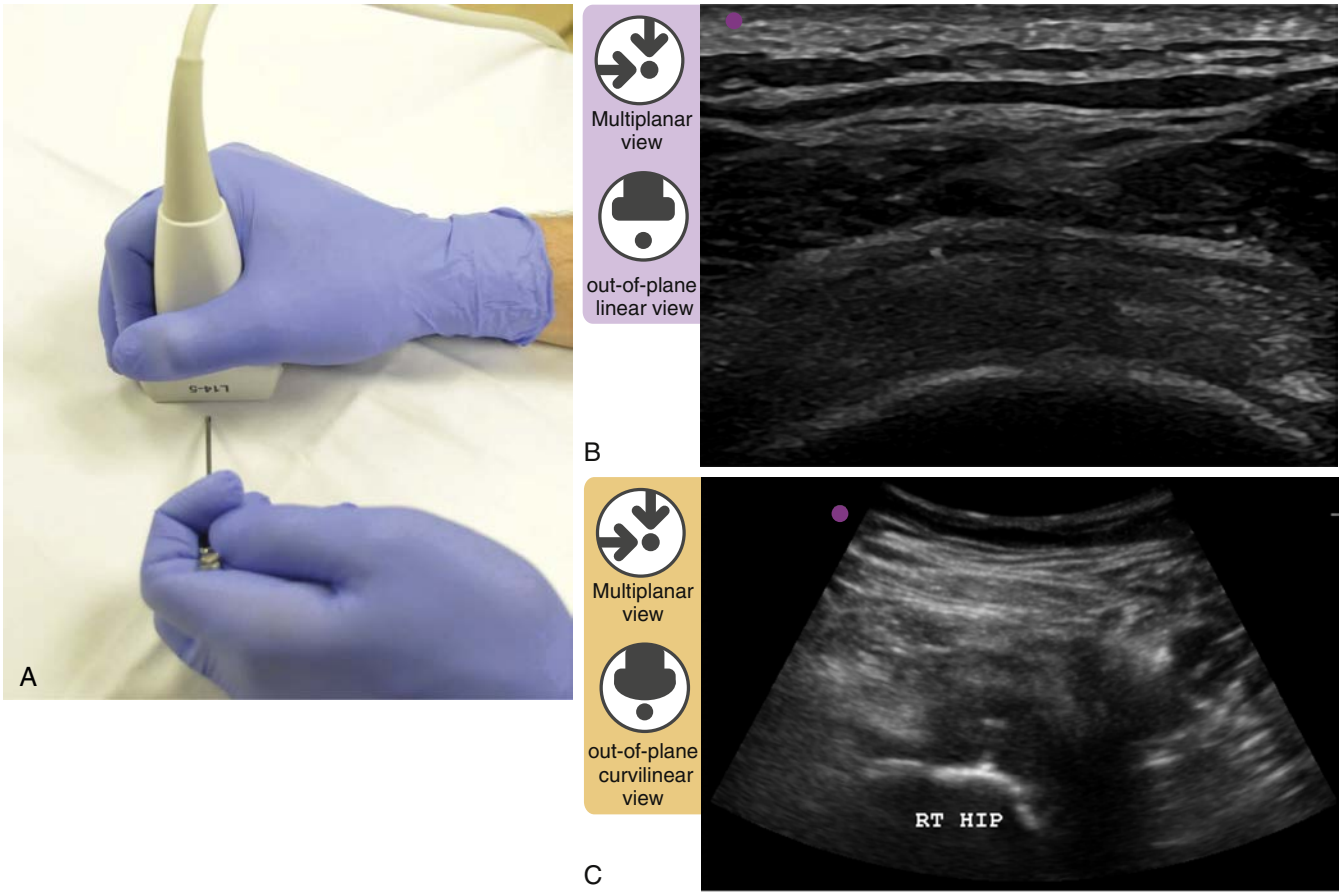

Fig. 1.13. A, Simulated out-of-plane (OOP) needle placement with the needle parallel to the linear transducer orientation. **B,** Example of an ultrasound (US) image of a subacromial/subdeltoid injection using a linear transducer with OOP needle placement (shown as white dot) with associated OOP linear icon. **C,** Example of US image of a hip injection using a curvilinear transducer with OOP needle placement (shown as white dot) with associated OOP curvilinear icon. The multiplanar icon is also shown since these are confirmatory views associated with the prior in-plane images.

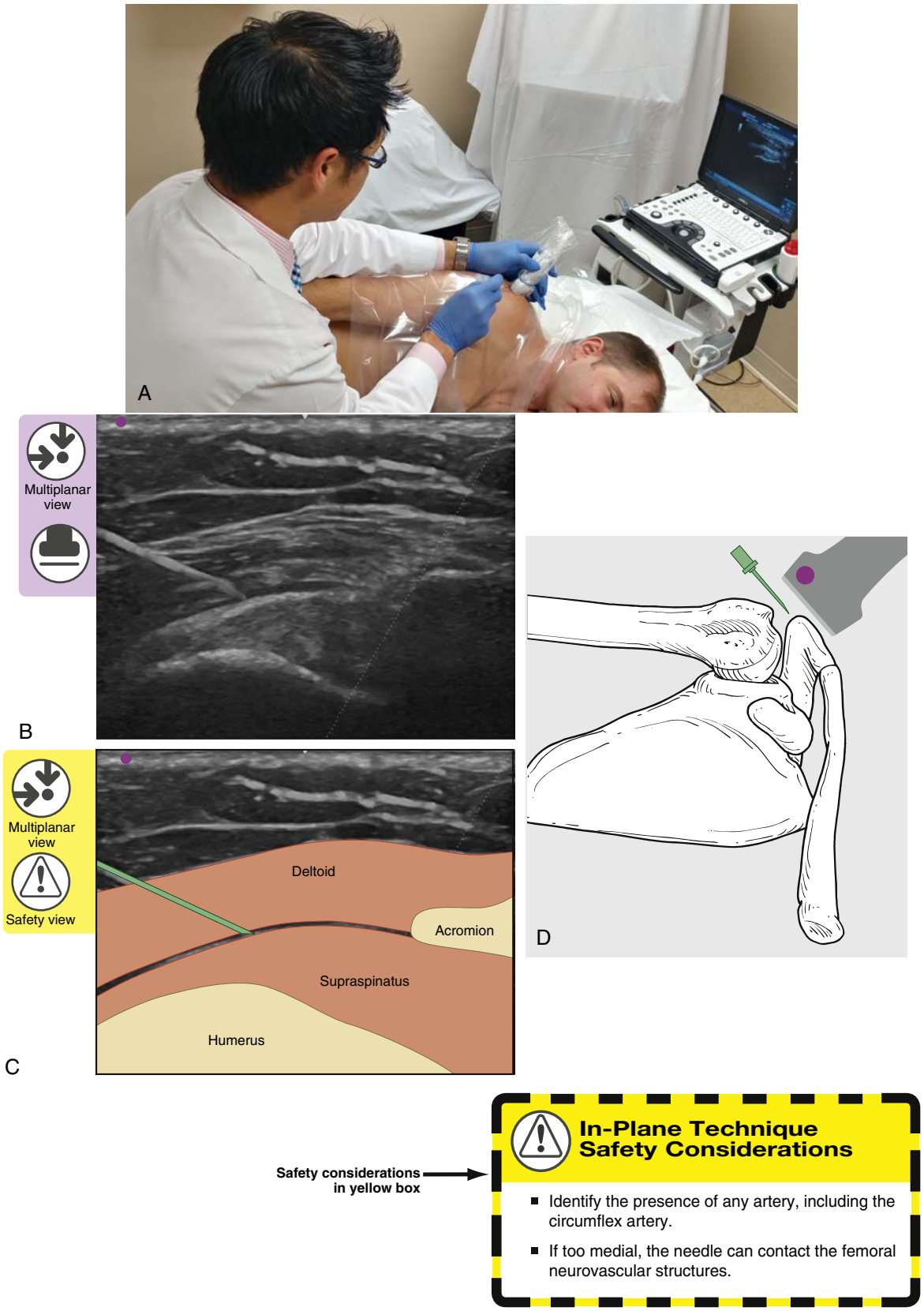

Fig. 1.14. Sample ultrasound page with our typical convention: **A** depicts the recommended room setup with the US screen relative to the patient, transducer and practitioner. We typically recommend the screen is on the opposite side as discussed in Chapter 4. The top left picture (usually **"B"**) contains the actual ultrasound image with the relevant ultrasound icon. The bottom left (typically **"C"**) includes a drawing of the same **"B"** image with relevant structures labeled. When the drawing has a larger field than the ultrasound image, we use a yellow dashed border on the drawing, demonstrating the anatomy visualized by the ultrasound image. When this is a safety view, the safety considerations are listed and a yellow border is placed along the **"C"** image. The top right **"D"** demonstrates a cartoon of the transducer (represented by a rectangle or transducer drawing) over the green needle and relevant anatomy. A purple dot indicates the transducer side that is on the screen's left side. We may have occasional extra drawings, diagrams, or images on this page for further orientation. In particular, structures that should be avoided are shown and described. Note that we typically label the drawing and not the ultrasound image.

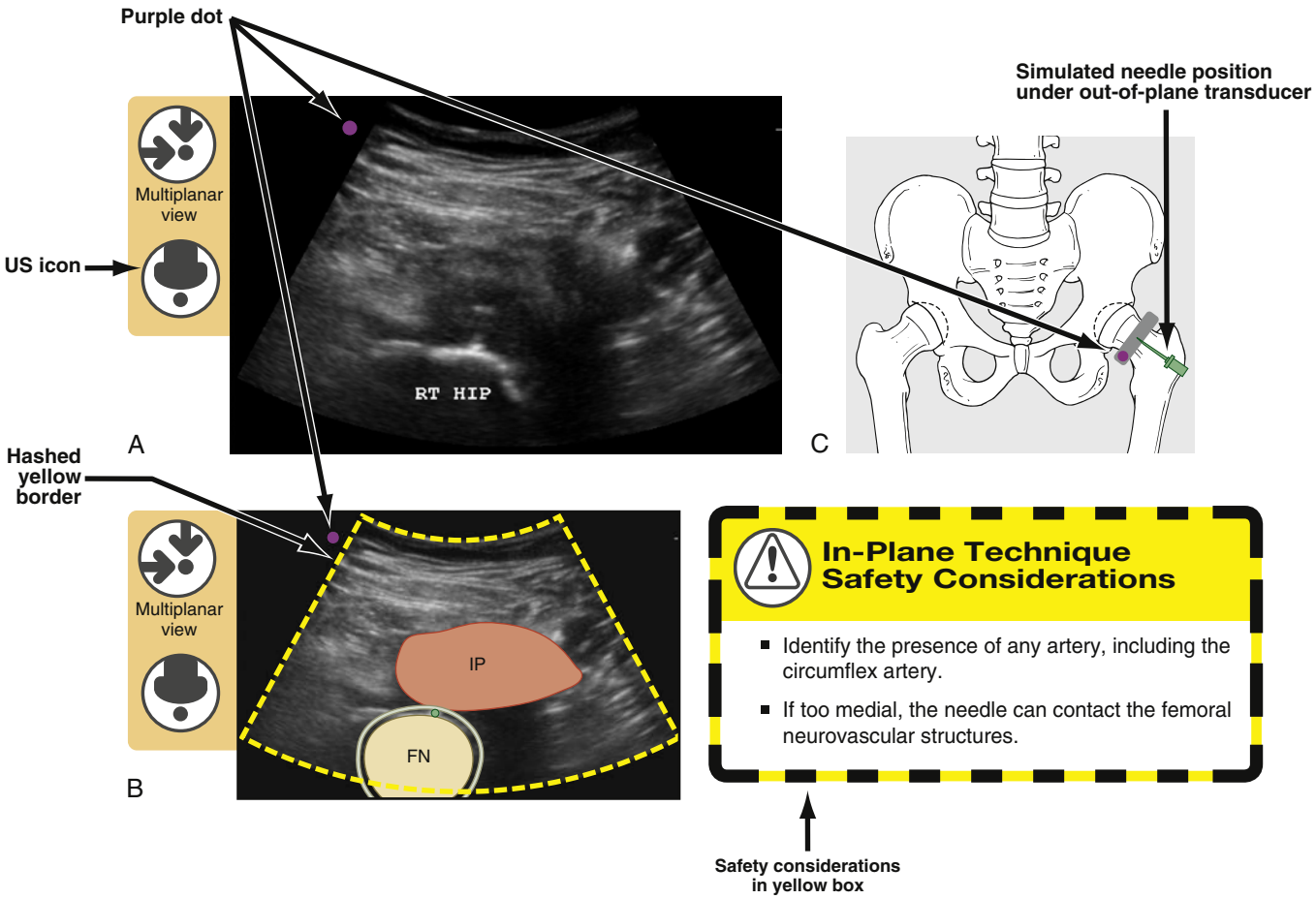

Fig. 1.15. Sample confirmatory multiplanar ultrasound page with our typical convention, with the top left picture (usually **"A"**) containing the actual ultrasound image with the relevant ultrasound icon. The bottom left (usually **"B"**) is a drawing of the same **"A"** image with the appropriate structures labeled. When the drawing has a larger field than the ultrasound image, we use a yellow hashed border on the drawing to demonstrate the anatomy visualized by the ultrasound image. The top right (usually **"C"**) green needle and has a cartoon of the transducer (represented by a rectangle or transducer drawing) over the green needle and relevant anatomy. When there is a safety view, the safety considerations are listed. In particular, structures that should be avoided are shown and described. Note that we typically label the drawing and not the ultrasound image. The purple dot on the transducer corresponds to the left of the screen.

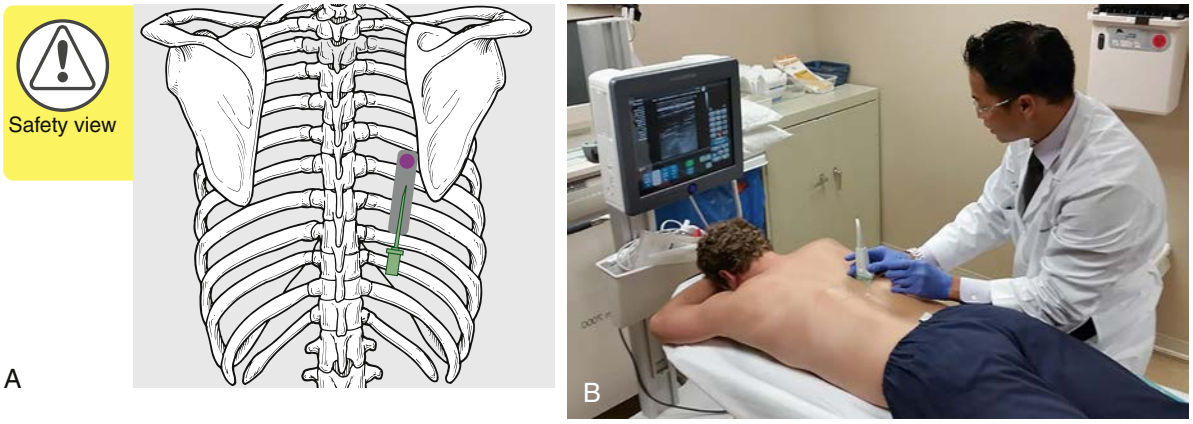

Fig. 1.16. A, Sample "rectangle/needle with purple dot" used to represent "bird's eye view" of ultrasound transducer and needle on a simulated patient during an ultrasound-guided intercostal nerve injection. **B,** Photograph of a simulated patient setup with transducer in place, demonstrating the transducer position and needle placement that the rectangle/needle icon is meant to represent.

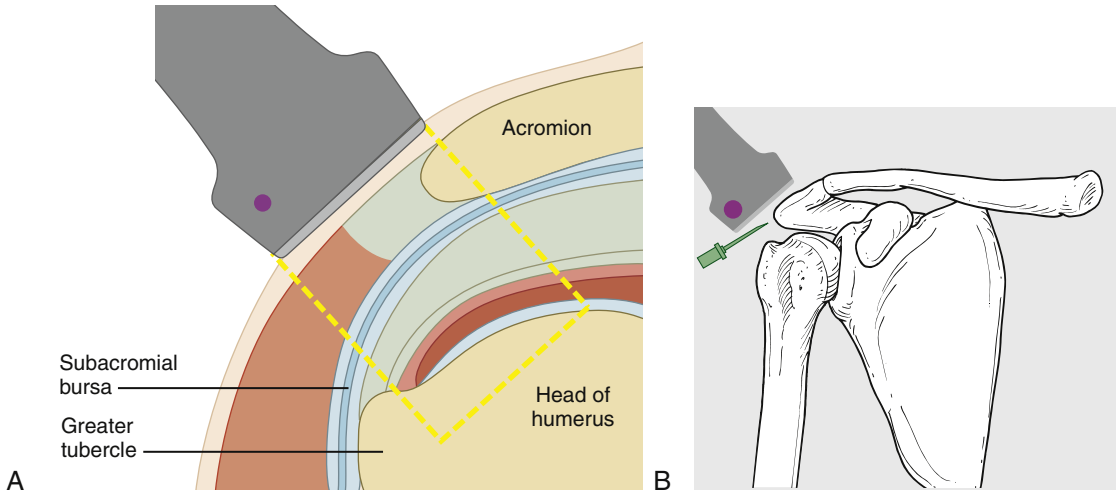

Fig. 1.17. A, Example of the two-dimensional representation of a "side view" of the ultrasound transducer and green needle on a simulated patient during a subacromial/subdeltoid injection. **B,** Associated drawing of the transducer placement.

SUMMARY

This introductory chapter assists the reader with understanding how to effectively use this atlas. A consistent set of fluoroscopic and ultrasound views are provided throughout the atlas, and these are denoted by the appropriate icons. The setup for each fluoroscopic technique is demonstrated via the trajectory view. Ultrasound procedures also start with appropriate room "setup" and the appropriate transducer and IP or OOP technique icons. Multiplanar imaging, optimal and suboptimal contrast flow patterns, and needle positions are demonstrated, and safety views, anatomic concerns, common pitfalls, and "pearls" are described. Suggested room setups and patient positions are shown. Fluoroscopic- and ultrasound-guided hybrid techniques are described when appropriate. By using a systematic approach, we hope that this atlas will allow you to perform fluoroscopic- and ultrasound-guided procedures more accurately, safely, efficiently, and with less patient discomfort.

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CHAPTER 2

Needle Techniques

Jonathan S. Kirschner and
Michael B. Furman

Many aspects are involved in a technically successful, efficient, and safe spinal injection procedure. These aspects are discussed in Box 2.1. This chapter focuses on item 4 from that list: directing or "driving" the needle tip into proper position.

Box 2.1

Keys to a successful fluoroscopically guided interventional spinal procedure:

1. Identifying where the target is anatomically located
2. Respecting the structures that are to be avoided and knowing their locations
3. Identifying which radiographic views (i.e., the trajectory and safety views) best facilitate a safe and direct pathway to the target while avoiding other structures as appropriate
4. **Successfully directing the needle tip toward the target with the use of multiplanar imaging**
5. Confirming placement with real-time contrast enhancement and multiplanar imaging

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

NEEDLE ANATOMY

To understand spinal needle manipulation, the interventionalist needs to be completely familiar with the anatomy of a typical spinal needle (Fig. 2.1). Quincke needles (Fig. 2.2) were developed in 1891 and have a sharp cutting bevel that is designed to perform dural punctures. They remain widely used today, although only for interventional pain procedures where dural puncture is *not* the goal. Medication flows out from the needle tip, so the distal tip observed on fluoroscopy can be used as a reference to determine from where the injectate is emanating. Whitacre needles (Fig. 2.2) have a blunt, pencil-point tip and are designed to spread tissues without cutting them, theoretically reducing the incidence and severity

Fig. 2.1. The Quincke-type spinal needle. The bevel is the opening adjacent to the needle tip where the injectate exits. The notch is the raised line or indentation at the hub end of the needle, and it is in line with the bevel. The notch is used as a marker to orient oneself to the needle's bevel position and potential direction or path after it is embedded in the tissue.

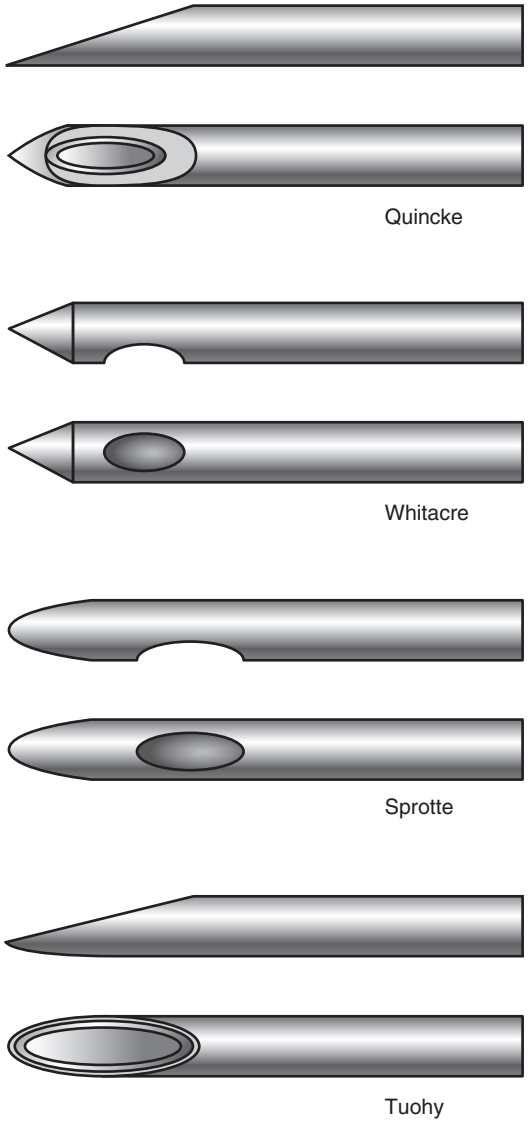

Fig. 2.2. Comparison of different needle types: Quincke, Whitacre, Sprotte, and Tuohy. We typically utilize the Quincke needles for most non-interlaminar procedures owing to their steerability and the spread of medication at the direct site of the needle tip. Note the curved undersurface of the Tuohy needle, which causes it to deviate toward the bevel (notch), unlike the Quincke needles.

of post-dural puncture headache (PDPH).* Original Whitacre needles had a small side port so anesthetic slowly flowed. Because the side port is not located at the tip, the needle may penetrate the subarachnoid space, but the anesthetic flows epidurally. Newer versions of Whitacre needles have a larger side port, which is located more distally. Whitacre needles are advocated for obstetric anesthesia because of their lower risk for PDPH. The Sprotte needle (Fig. 2.2) is one variation of the pencil-point design. It may allow for more unilateral flow during spinal anesthesia and may facilitate catheter spread through the side port. Because these modifications are mainly designed for intrathecal use and the goal of most pain procedures is the spread of medication at the direct site of the needle tip, the authors prefer to use Quincke-type needles for all but interlaminar procedures. The bevel may be short or long, with the short bevel theoretically producing less tissue damage. However, short bevels have not been shown to reduce the risk for vascular injury. The Tuohy needle has a long, curved bevel with a sharp distal tip that is often utilized to safely enter the epidural space and facilitate the introduction of catheters. The Tuohy needle has a smooth proximal bevel to reduce the risk for cutting a receding catheter. The hub is often used to assist with catheter steering at the needle tip. The Tuohy and Crawford needles are preferred for interlaminar epidural procedures because of their blunt tips, which allow interventionalists to better feel the ligamentum flavum and loss of resistance. The authors prefer to use Tuohy needles for interlaminar epidural injections with or without catheter use.

BEVEL CONTROL

Because of the angulation of the bevel in a Quincke needle, the needle moves in the direction of the pointed needle tip, which is away from the bevel (Figs. 2.3 and 2.4). The notch, at the proximal end of the needle, denotes the side on which the bevel is placed. Understanding and using the needle's property of movement away from the bevel is known as *bevel control.* This concept is primarily useful for triangular tipped Quincke-type spinal needles, as opposed to pencil-point needles such as the Whitacre or Sprotte needles. Because of their curved base, the Tuohy needles actually slightly deviate *toward* the bevel or notch.

Fig. 2.3. Bevel control. The needle tends to advance toward the sharper, needle tip, side and away from the bevel (open) end of the needle tip.

BENDING THE NEEDLE TIP: ENHANCED STEERABILITY

To accentuate bevel control and to improve the user's ability to "steer" the needle, the interventionalist may place a 5- to 10-degree angle bend at the needle's tip. This angle bends away from the bevel and toward the tip (Fig. 2.5). This enables finer directional control. Because the needle does not have to be retracted and redirected as frequently, there may be less tissue damage, procedure time, and pain. An unbent needle will tend to move more directly from the skin to the target's vicinity but will be harder to redirect once at depth. A bent needle allows for finer control but when advanced may require more frequent adjustments compared to a straight needle. Typically, the bend is most effective in the distal 0.5 to 1 cm closest to the tip. More bend is used when more maneuverability is needed. For example, L5-S1 discography or a transforaminal injection around a fusion mass may require a 30-degree bend, whereas a medial branch block may require only 5 to 10 degrees.

When bending the needle tip, avoid touching it with a gloved hand, which can become punctured, compromising sterility. Instead, use a sterile gauze pad or a hemostat. Try to make a smooth bend rather than a sharp one to facilitate easier stylet removal.

NEEDLE GAUGE

Smaller gauge needles have a thicker diameter, whereas larger gauge needles have a thinner diameter. The thinner needle responds more to bevel control. Spinal procedures that require fine needle control (e.g., zygapophysial joint injections, transforaminal epidurals, medial branch blocks, discography) are typically performed with either 22- or 25-G needles. However, effectively bending the needle gives it a thicker (i.e., decreased) gauge. For example, when performing discography for a disc with a significant loss of height, an unbent needle will be easier to navigate in a narrow space than a bent (i.e., thicker) needle.

*Please see page ii for a list of anatomical terms/abbreviations used in this book.

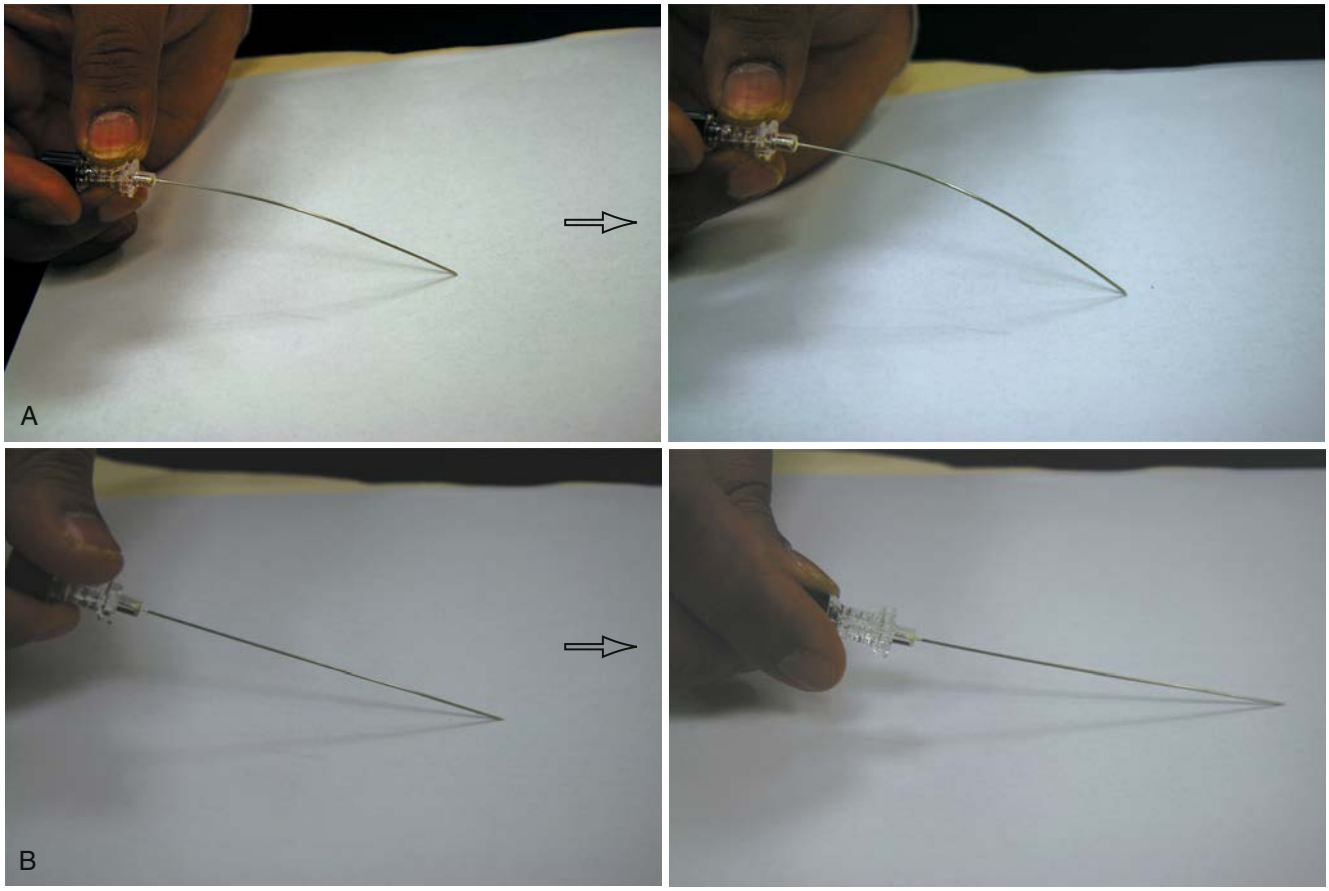

Fig. 2.4. A, An unbent Quincke needle being slid along the surface with the needle tip down and the bevel up. **B,** The same needle being slid along a flat surface with the bevel down and the needle tip up. When the needle tip is down, it engages the surface and bends toward the tip and away from the bevel (top right panel). In a tissue, the same phenomenon will occur, thus directing the needle toward the needle tip and away from the bevel side. The use of this property allows one to maintain control of the needle tip direction and to keep it from moving away from the bevel (bevel control).

Fig. 2.5. A needle bent toward the sharper needle tip accentuates the bevel control and improves needle steerability. When advancing a bent needle, its direction may require more frequent adjustments compared with a straight needle because of its steerability.

NEEDLE DRIVING

When the needle is embedded within the patient, all that is seen is the needle's hub end (Fig. 2.6). The notch is the steering wheel used to direct the needle tip based on the principles noted in this chapter. Driving a needle is analogous to driving an automobile. The thicker, unbent needles (e.g., Tuohy needles) are like trucks, and the thinner (22- or 25-G spinal needles), bent needles are like sports cars. Larger vehicles, much like thicker needles, tend to stay on their given trajectory once they have been advanced, and larger movements are required to make gross adjustments. One could take their hands off the steering wheel—although this is not recommended—and a truck would likely still drive straight. Thinner needles are like sports cars; they can make more exaggerated movements, but they require constant manipulation and fine-tuning to stay on their intended path.

Thicker needles and introducers (i.e., 20 G and larger) respond less to bevel control and more to "leverage." With "leverage," as the hub of the needle is moved in one direction, the needle tip will move in the opposite direction, with the

skin surface acting as the fulcrum (Fig. 2.7). When the needle is placed on its intended path, it will tend to stay on that trajectory, which is useful for situations such as interlaminar procedures.

Fig. 2.6. When the needle is embedded within a tissue, only the hub end is visualized. The notch is used as a marker to orient oneself to the embedded needle tip's bevel position, as demonstrated in Fig. 2.1.

CONCAVITY (FINGER FULCRUM)

If more exaggerated repositioning is needed than is allowed with bevel control or "leverage," a fulcrum can be created above the skin level to help guide the needle into position (Fig. 2.8). By directly manipulating the needle, the fulcrum allows a greater horizontal force to be applied to the needle while it is anchored at the skin level. This can be helpful when navigating around a fusion mass or for accessing difficult discs during a discogram. This should be combined with bevel control techniques.

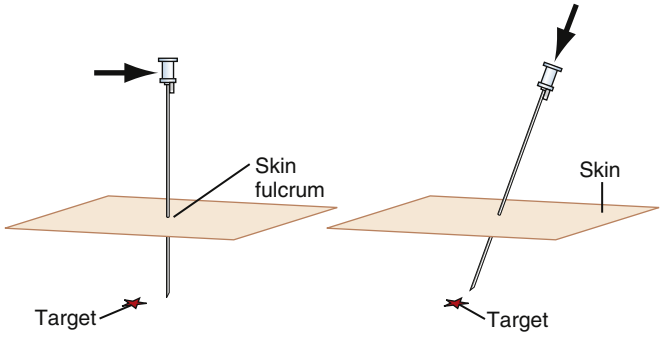

Fig. 2.7. The "leverage" method, with the needle in the skin and the skin acting as a fulcrum. This method works best with thicker, smaller gauge needles.

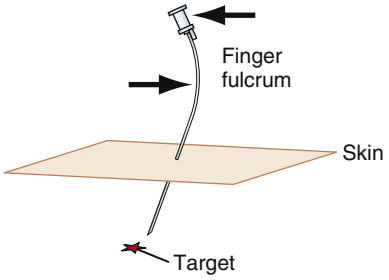

Fig. 2.8. Concavity (finger fulcrum) for thinner, higher gauge needles. If more exaggerated maneuvers are needed, a fulcrum helps to guide the needle tip as it advances toward the target. This method should be combined with bevel control techniques.

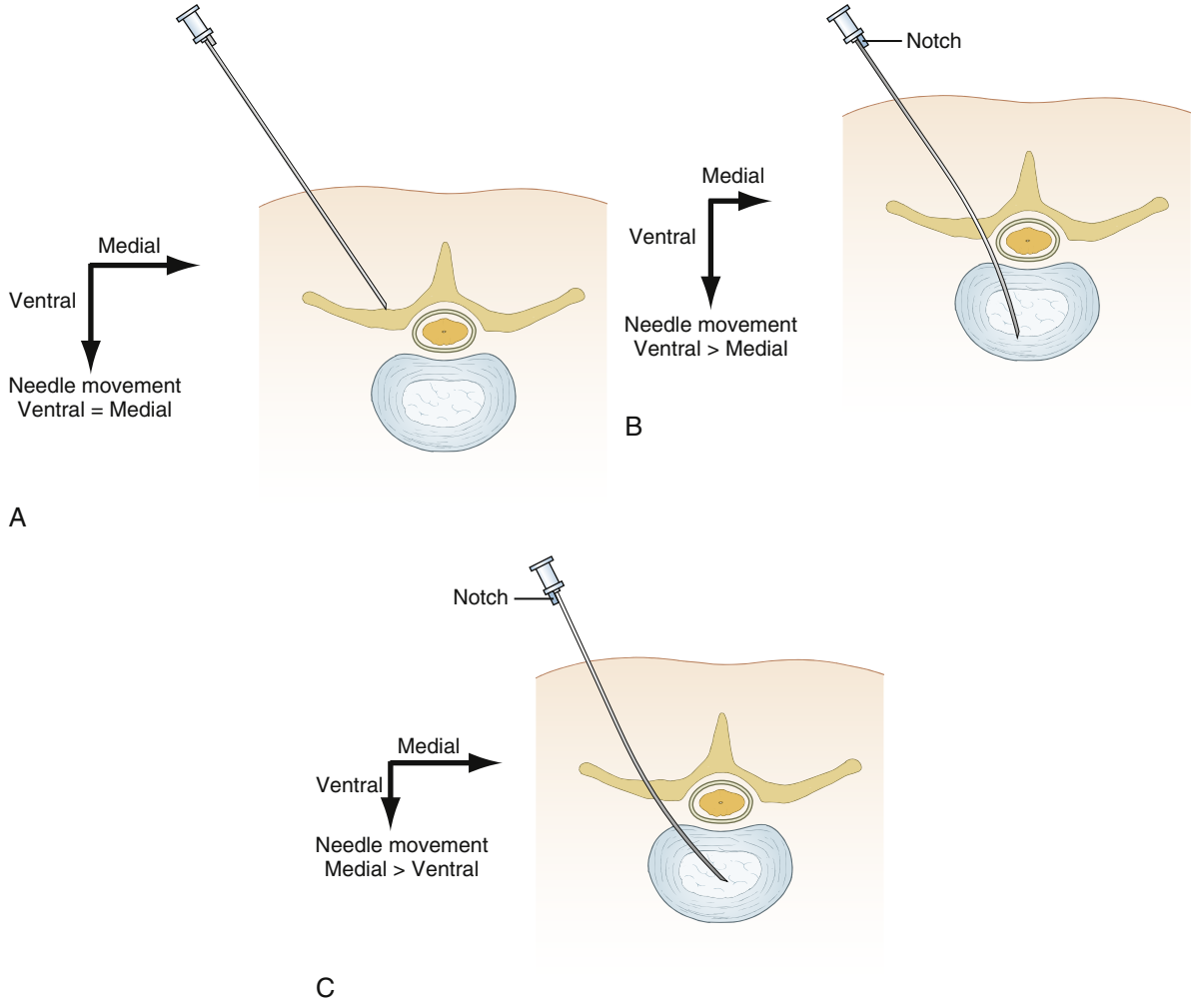

Fig. 2.9. A, Needle advancement with an oblique trajectory. Note that the simulated needle is headed toward the center of the intervertebral disc. **B,** Directing the needle with the notch medial places a significant ventral vector on the needle. Although it moves more ventrally, the needle continues to move medially and not laterally. **C,** Placing the notch lateral drives the needle more medially as it also continues with its ventral vector.

MEDIAL VERSUS VENTRAL NEEDLE ADVANCEMENT

We are often asked to clarify why we describe *medial versus ventral* needle driving instead of *medial versus lateral* movements. As a needle advances toward a target starting with an oblique projection (Fig. 2.9A), its trajectory can be broken into two predominant vectors: *medial* and *ventral*. After a needle is embedded in a tissue and on its given path, placing the notch laterally will drive the needle tip *medially* (Fig. 2.9B). Likewise, placing the notch medially will drive the needle tip *ventrally* (Fig. 2.9C).

As shown in Fig. 2.10, as the needle is being advanced ventrally into the tissue, it obviously cannot be advanced dorsally back to the skin surface. Likewise, a needle with an oblique trajectory can be advanced *medially* toward the midline but cannot be advanced back laterally toward the needle skin entry point.

However, if a needle trajectory is less oblique and more perpendicular to the skin surface (Fig. 2.11), then a *lateral* needle tip movement can be achieved.

"THE MOVE"

When performing procedures, the interventionalist may encounter a bony obstruction. One trick to overcome this is what we call "the move." This is a "tactile" technique using a bent needle. When an obstruction to the needle passage is encountered, the operator rotates the needle tip by 180 degrees to negotiate around and clear the

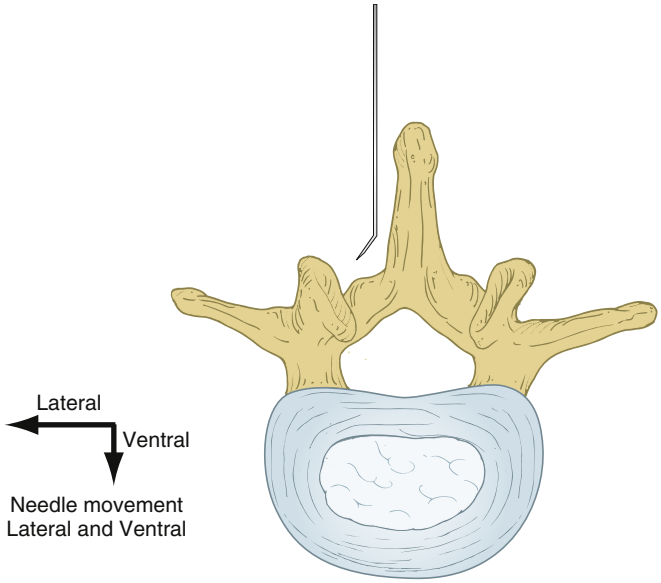

Fig. 2.10. Advancing the needle with less of an oblique angle increases its ability to move laterally. Contrast this with Figure 2.9 with an oblique needle angle entry.

obstruction. Once the needle can pass, the operator immediately rotates the needle tip 180 degrees to restore the original bevel orientation and to get back on target, thereby avoiding too much needle deflection.

FINGER DEPTH GAUGE

When imaging demonstrates that a major needle repositioning is in order, the only way to redirect the needle is to retract and redirect it. If the needle is at a safe depth, it can be easily redirected to a similar safe depth by pinching it at the skin surface to mark the depth, retracting it, and advancing it until the same location is reached at the same fingertip depth. Some needles do have depth gauges but are not clearly marked or are not as easy or accurate to use.

EXTENSION TUBING

When the needle tip is considered to be in its final position and when this is confirmed with multiplanar imaging, non-ionic contrast should be injected during real-time ("live") fluoroscopy to visualize the potential flow of the injectate and to assess for vascular uptake. Microbore extension tubing is recommended to allow increased distance between the operator's hand and the X-ray beam, thus minimizing radiation exposure. Extension tubing also minimizes needle tip movement when syringes are exchanged or when contrast or medication is instilled. A helpful tip is to keep one hand on the extension tube while the other hand changes the syringe to further minimize needle displacement (Fig. 2.11).

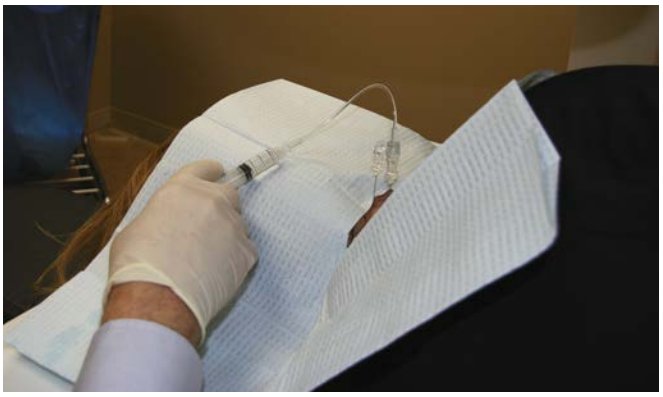

Fig. 2.11. During this cervical procedure, the physician braces his hand against the patient's head to minimize needle traction and displacement while keeping his hand away from the radiography beam to minimize radiation exposure.

SUMMARY

Interventionalists can direct a needle in three ways. “Leverage” is used for thicker needles. Bevel control can be used for finer manipulation, especially when the needle is bent. When exaggerated movements are needed, concavity can be used to sharply change directions without retracting the needle, especially when thinner needles are used. Understanding how needle anatomy and gauge affect movement allows for more effective spinal procedures with less procedure time, fluoroscopic time, and patient discomfort.

References

1. Turnbull DK, Shepherd DB. Post-dural puncture headache: pathogenesis, prevention and treatment. *Br J Anaesth*. 2003;91:718–729.
2. Smuck M, Yu AJ, Tang CT, Zemper E. Influence of needle type on the incidence of intravascular injection during transforaminal epidural injections: a comparison of short-bevel and long-bevel needles. *Spine J*. 2010;10(5): 367–371.

CHAPTER 3

Introduction to Fluoroscopic Techniques: Anatomy, Setup, and Procedural Pearls

Alan T. Vo, Ruby E. Kim, Jonathan S. Kirschner, Tejas N. Parikh, Isaac Cohen, and Michael B. Furman

This chapter describes basic and advanced fluoroscopy techniques to achieve optimal C-arm setups. These include an understanding of the C-arm operation, fluoroscopic anatomy, basic projections, optimal views, and parallax.

The first step to a successful procedure includes setting up the C-arm according to the anatomy of the specific targeted segment. The C-arm setup determines the trajectory that the needle will take to reach its target, provided that the operator uses "down the beam" technique. It should be evident that a safe, efficient, and effective procedure is dependent on an optimal C-arm setup.

The authors would like to emphasize that the setup should be specifically focused on the target segment. Visual recognition of bony landmarks, rather than specific measurements or angles, is emphasized, given that the morphology and orientation of each anatomic segment can differ.

The challenge for an interventionalist is to reconcile the two-dimensional configuration of the fluoroscopic image with the three-dimensional anatomy of the patient. Such an understanding requires time, practice, and knowledge of spinal anatomy and fluoroscopy.

In the latter half of the chapter, these more "advanced" fluoroscopic techniques will help the reader obtain the skills needed to troubleshoot any nonoptimal image, and therefore provide the safest and most efficient procedure for the patient.

The following fluoroscopic techniques will help to optimize the visualization of key bony landmarks when positioning the needle to reach a specific target.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Review of Spine Anatomy (Fig. 3.1)

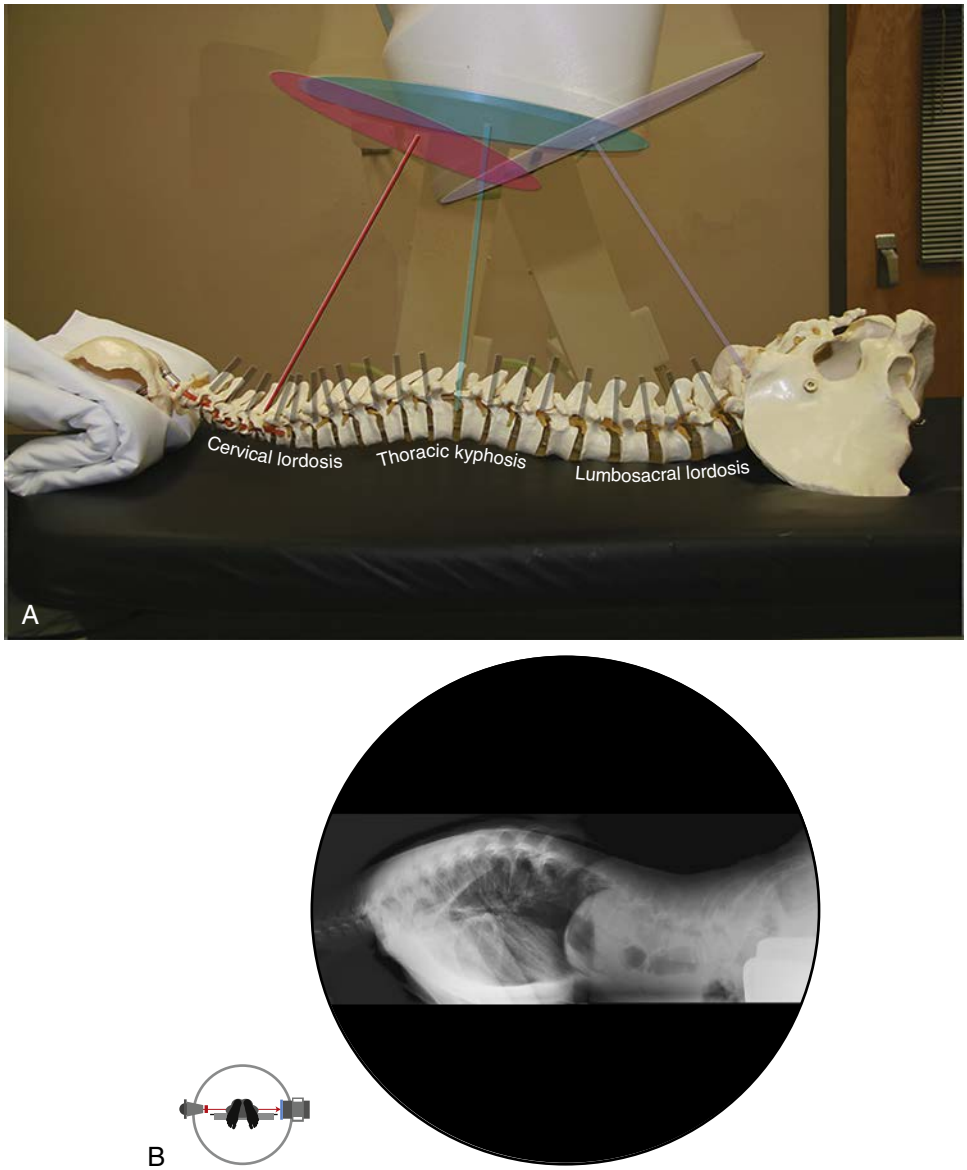

Fig. 3.1. A, Model of a spine in the lateral position, with needles at different angles demonstrating the natural curvature (i.e., lordosis or kyphosis) of the spine. Note the different C-arm tilt angles for the needle trajectories at each spinal segment. **B,** Lateral radiograph of a spine demonstrating cervical lordosis (not well visualized on the far left of image), thoracic kyphosis, and lumbar lordosis. Compare with Fig. 3.1A to anticipate needle trajectories for each spinal segment.

C-Arm Equipment (Figs. 3.2 and 3.3)

Fig. 3.2. A, Cone-shaped fluoroscopic beam coming from the smaller diameter image source to the larger diameter image intensifier. The nomenclature used throughout this atlas is based on the movements of the larger diameter image intensifier and not the beam or image source. **B,** Monitors with lateral image and patient information. **C,** Foot pedal. **D,** Control panel on the fluoroscope base unit. **E,** Control panel on the monitor.

C-Arm Movements and Nomenclature (Fig. 3.3 and Table 3.1)

Table 3.1 Definitions of the Different C-Arm Movements and the Nomenclature Used Throughout This Atlas*

Movement	Figure/ Photograph/ Diagram of Movement	Description	Nomenclature Used in This Atlas
Cephalad or caudad tilt (also known as decline)	Fig. 3.3A and B	The C-arm rotates around a transverse axis with the image intensifier (ImInt) rotating superiorly while the X-ray source rotates inferiorly (or vice versa). If the patient is side-lying, this will create a similar motion relative to the patient as wig-wag in patients in the supine or prone position (Table 3.3).	0-degree tilt: straight up and down (perpendicular to the patient). The ImInt toward the head is cephalad tilt and toward the feet is caudad tilt.
Oblique	Fig. 3.3C, D, and E	The C-arm rotates circumferentially (ImInt right or left) and moves around the patient either toward or away from the interventionalist.	0 degrees: anteroposterior (straight up and down). 90 degrees: lateral. The ImInt toward the right is right oblique.The ImInt toward the left is left oblique. The C-arm toward the needle tip is ipsilateral oblique and away from the needle tip is contralateral oblique (CLO).

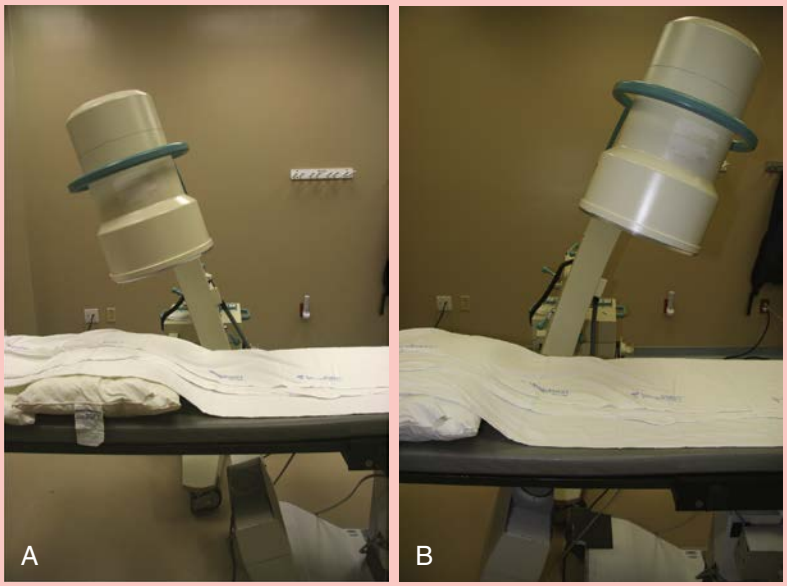

Fig. 3.3. A, Cephalad tilt of the fluoroscope. **B,** Caudad tilt of the fluoroscope.

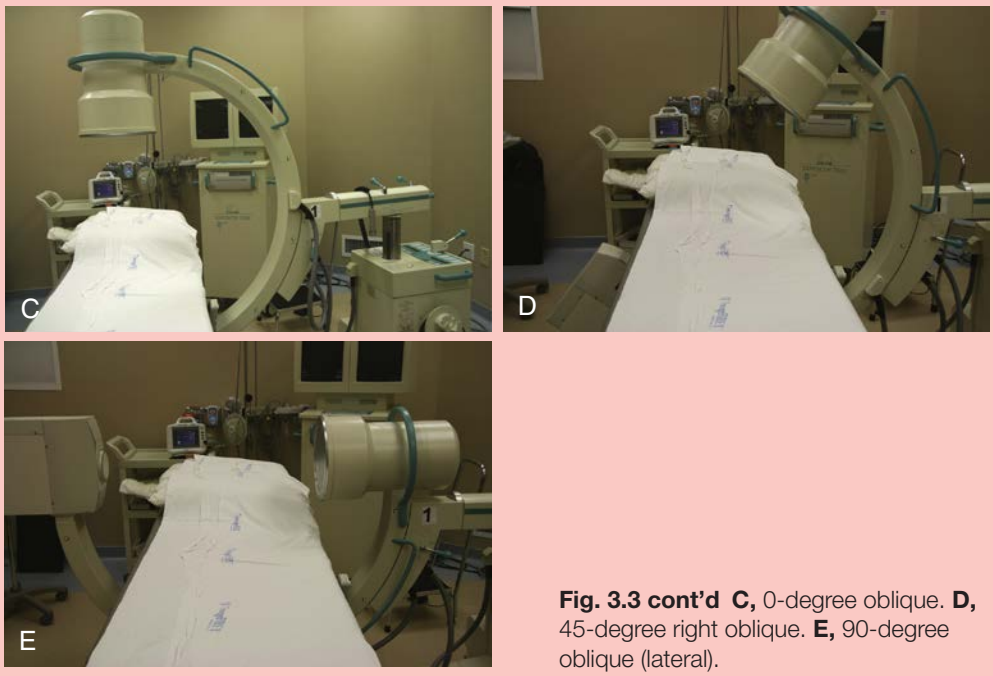

Fig. 3.3 cont'd C, 0-degree oblique. **D,** 45-degree right oblique. **E,** 90-degree oblique (lateral).

Table 3.1 Definitions of the Different C-Arm Movements and the Nomenclature Used Throughout This Atlas*—cont'd

Movement	Figure/ Photograph/ Diagram of Movement	Description	Nomenclature Used in This Atlas
Piston (also known as in/out translation, left/ right translation, or telescope)	Fig. 3.3F	The C-arm translates toward the patient's right or left. Fig. 3.3F depicts this in the anteroposterior (AP) view (0-degree oblique). Pistoning can also be done with the C-arm in other oblique angles, including the lateral view (90-degree oblique). When in the lateral position, the ImInt movement toward or away from the patient can make the image less or more magnified, respectively.	The C-arm is to the patient's right or left.
Head/foot translation		The entire C-arm moves parallel to the patient, either superiorly toward the head or inferiorly toward the feet. The direction of C-arm translation is dependent on which way the wheels are facing. Most machines can be locked to only translate in one plane at a time.	The C-arm translation is cephalad or caudad.
Up and down (ceiling/floor elevation)		The C-arm moves toward the ceiling or the floor. The ImInt moves toward or away from the patient, thus making the image less or more magnified, respectively.	The C-arm is up toward the ceiling or down toward the floor.
Wig-wag (swivel)	Fig. 3.3G	The wig-wag technique involves the use of a third plane of axis. It is typically used while the C-arm is in a lateral position (i.e., 90-degree oblique), with the C-arm's ImInt rotating inferiorly while the source rotates superiorly (or vice versa). The typical goal of this technique is to position the X-ray beam perpendicular to the imaged target structure and/or needle. This motion is also used to separate overlapping structures or needles. Because the rotation axis is actually around the C-arm base (and not the patient), the C-arm typically will need to be translated back to the treated segment after the wig-wag movement. If the patient is side-lying, this will create a similar motion relative to the patient as tilting in the supine or prone position (Table 3.3).	The C-arm wig-wag rotation is around the patient either clockwise or counterclockwise.

Fig. 3.3 cont'd F, Pistoning of the fluoroscope. The left arrow indicates pistoning toward the interventionalist, and the right arrow indicates pistoning away from the interventionalist.

Fig. 3.3 cont'd G, Wig-wag of the fluoroscope demonstrating both 0 degrees and approximately 20 degrees of clockwise wig-wag relative to the patient.

*The terminology is based on the image intensifier (ImInt, and not the image source) movements.

Identifying Spinal Segments/Confirming the Levels (Figs. 3.4 to 3.8)

Cervical

For a patient with normal spinal segmentation, identify the level by counting cephalad from the cervicothoracic junction in the anteroposterior (AP) view or down from the C2/axis (with the odontoid process/dens) in the lateral or AP projection. For procedures that will be performed in the oblique projection (i.e., cervical transforaminal), identify the level by locating the most superior intervertebral foramen, which is the C2-C3 foramen where the C3 spinal nerve exits, and then count caudad. The C7 and T1 segments are transitional vertebrae and thus have intermediate features in relation to the cervical and thoracic spine. The C7 transverse process (TP) is longer than its cervical counterparts but shorter than the T1 TP. It appears slightly downsloping and has a configuration that can be likened to that of a "short, stubby thumb." The T1 TP is longer than the C7 TP, broader than the thoracic TPs, and slopes upwards superolaterally (Fig. 3.4).

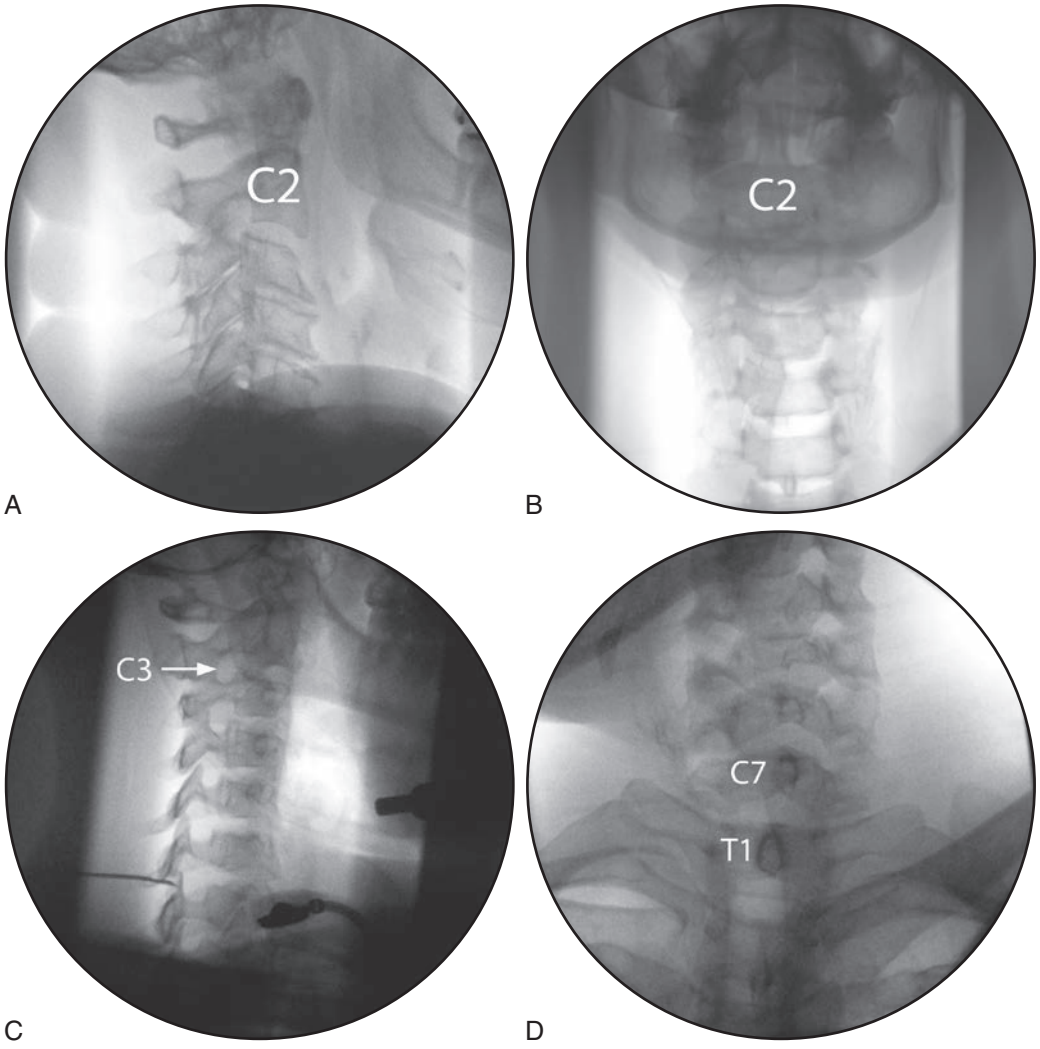

Fig. 3.4. A, Fluoroscopic lateral view of the cervical spine with C2 (axis) labeled. Note that the spinous process of C2 is bifid. **B,** Fluoroscopic anteroposterior (AP) view of the cervical spine with C2 labeled. **C,** Fluoroscopic foraminal oblique view of the cervical spine with the C2-3 foramen; where the C3 spinal nerve exits is labeled. Note that the most superior neural foramen of the cervical spine is C2-3 (labeled "C3"). A spinal needle approaches the C6-7 neural foramen, where the C7 spinal nerve exits. **D,** Fluoroscopic AP view of the cervicothoracic spine with C7 and T1 labeled. Note that the C7 transverse process (TP) is longer than its cervical counterparts but shorter than the T1 TP and appears slightly downsloping. The T1 TP is longer than the C7 TP, broader than the thoracic TPs, and slopes upwards superolaterally.

Thoracic

For a patient with normal spinal segmentation, identify the level in the AP view by counting caudad from the cervicothoracic junction (Fig. 3.4D) or cephalad from T12 (Fig. 3.5). The ribs can be used as a segmental counting guide, but caution must be taken. Some patients may have a cervical (extra) rib or may lack obvious T12 ribs, and therefore do not have 12 reliably distinct ribs for landmarks. Caution must be used when correlating the lowest thoracic rib to lumbar magnetic resonance imaging (MRI) findings because they are typically interpreted/enumerated on the basis of the lumbosacral junction (see Figs. 3.5 through 3.7).

Lumbosacral

For a patient with normal spinal segmentation, identify the level in the AP view by counting caudad from T12 (Fig. 3.5A) or cephalad from the lumbosacral junction (Fig. 3.5B). As stated above, the ribs can be used as a segmental counting guide, but caution must be taken. Some patients do not have 12 reliably distinct ribs for landmarks. Even when a distinct 12th rib is identified, atypical enumeration can occur (Fig. 3.6), as described in the next section.

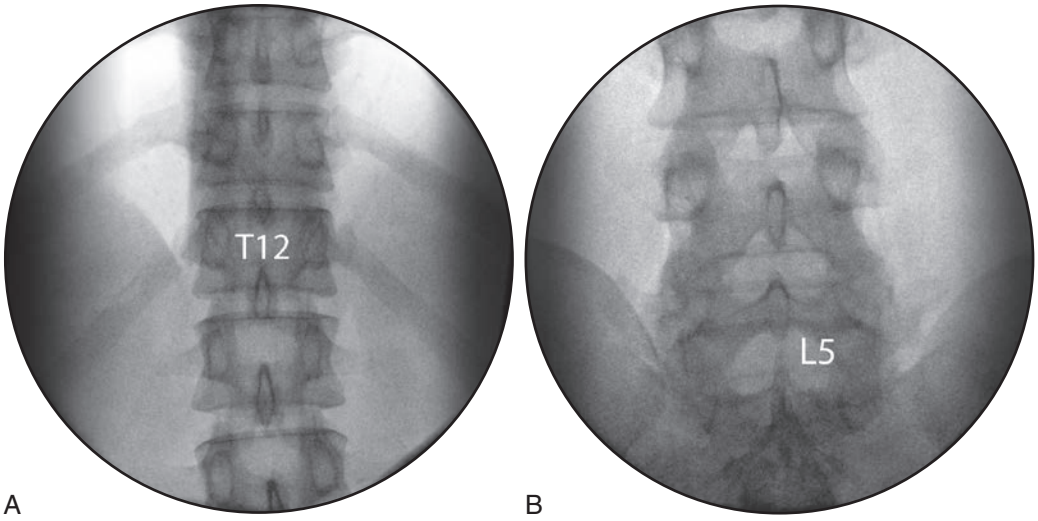

Fig. 3.5. A, Fluoroscopic anteroposterior (AP) view of the thoracolumbar spine with T12 labeled. **B,** Fluoroscopic AP view of the lumbosacral spine with L5 labeled.

Lumbosacral Transitional Segments/Atypical Segmental Enumeration

In up to 15% of the population, a transitional segment may occur. Transitional segments are typically described as involving the lumbarization of the first sacral segment or the sacralization of the fifth lumbar segment. Rarely patients will have six lumbar vertebrae, and some consider these to be lumbarized S1 segments because an L6 spinal nerve is typically not described. In fact, studies suggest that L6 segments do indeed behave like S1 segments; in patients with only four lumbar vertebrae, the inferiormost lumbar segment L4 behaves like L5.[1,2] Extra or missing ribs may add to the counting confusion (Fig. 3.6). Similarly, as discussed above, some patients may have an aberrant segmentation of the cervicothoracic junction, thoracolumbar junction, or both. Therefore, if a transitional segment is suspected, an MRI scout image is recommended for the purpose of counting caudad from C2 to the lumbosacral junction.[3] If a lumbosacral transitional segment is suspected, coronal T2 images should be specifically requested and/or the scout including C2 (Fig. 3.7) because they may not be routinely included with a lumbar MRI.

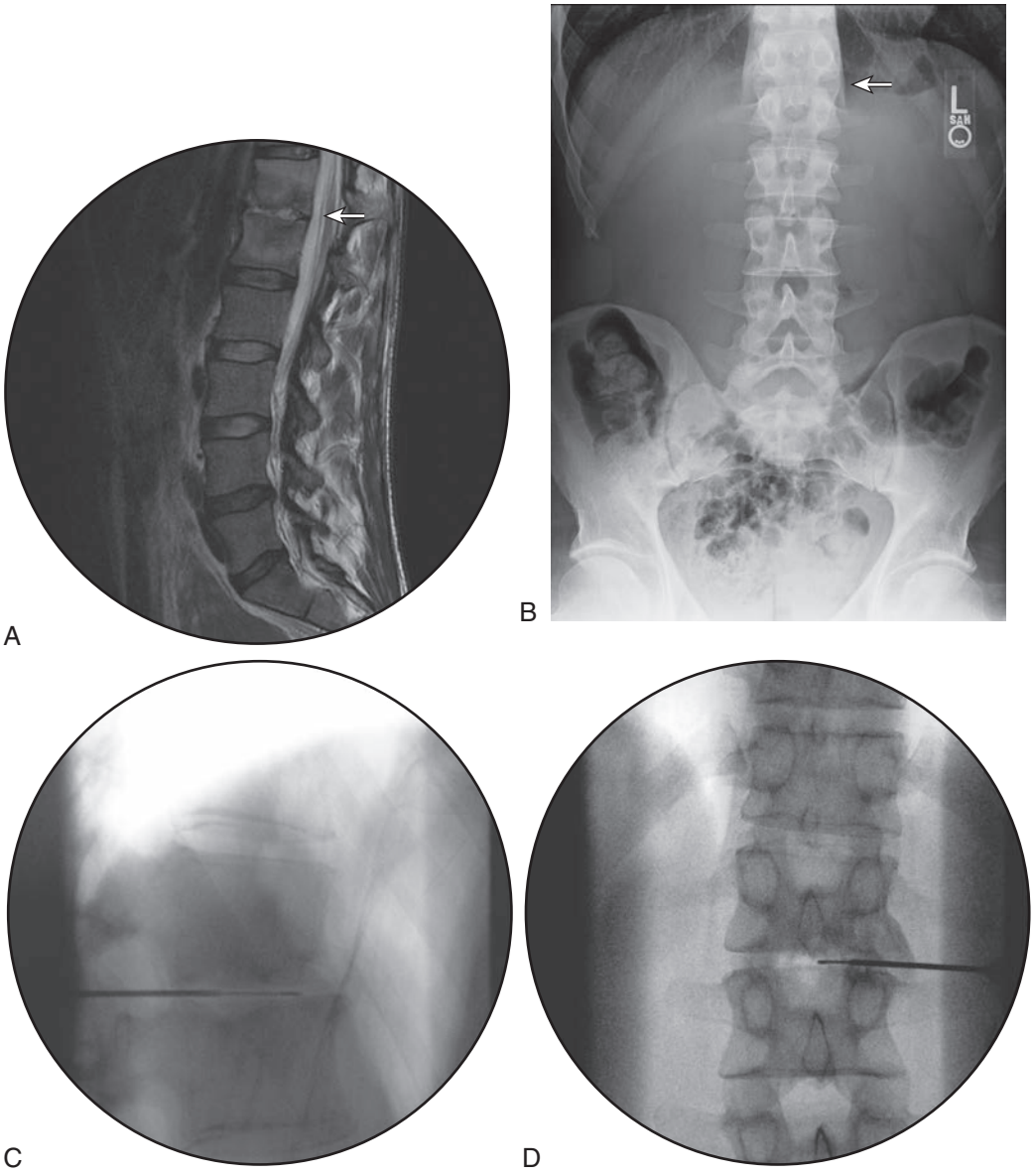

Fig. 3.6. A, This patient had a suspected "T12-L1" discitis identified on T2-weighted magnetic resonance imaging (MRI). The "T12-L1" level (arrow) was identified on the basis of counting up, superiorly, from the lumbosacral junction. **B,** AP plain film with the same "T12-L1" level identified (arrow) by counting up from the lumbosacral junction. Note its location relative to the thoracolumbar juction; **C,** intraprocedural fluoroscopic lateral; and **D,** intraprocedural fluoroscopic AP of the "T12-L1" disc biopsy. When we performed the fluoroscopically guided biopsy, **we correlated the fluoro and plain film images with the MR images by also counting up from the sacrum and confirming the narrowest disc as seen on MRI, plain film, and fluoroscopic imaging.** Note that we would have potentially chosen the wrong level had we only counted down from the most inferior rib on intraprocedural fluoroscopic AP.

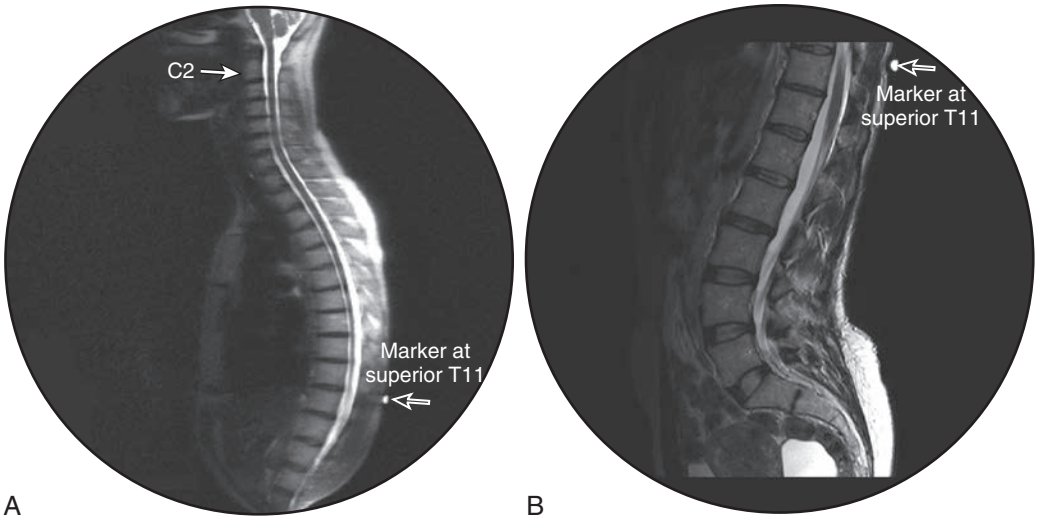

Fig. 3.7. T2-weighted scout localizer magnetic resonance imaging (MRI) that includes C2 for definitively determining proper segmental enumeration. "Markers" are placed on the dorsal skin prior to the MRI scan. **A,** Cervicothoracic segments. Note the C2 vertebral segment *(closed arrow).* A marker is demonstrated over the skin dorsal to the superior aspect of T11 *(open arrow)*. **B,** Thoracolumbar segments. The same marker is used to assist in counting down to the lumbosacral junction for definitive enumeration.

Ultimately, it is most important to correlate the patient's clinical symptoms with the pathoanatomy visualized on the available imaging. Subsequently, fluoroscopic images obtained during the procedure need to be correlated with the same visualized pathoanatomy. The demonstrated example (Fig. 3.8) is of a patient who has right L5 and/or S1 symptoms with MRI suggesting lumbarization of S1 and an extrusion at L5-S1 (yellow arrow). The intent was to administer medication along S1, with the contrast and medication directed superiorly toward the posterior L5-S1 disc.

We strongly encourage correlating the plain X-ray lateral and fluoroscopic lateral image with the midline sagittal MR image so that the proper levels are chosen. We cannot overemphasize the importance of documenting and communicating the transitional segmental convention used with other treating physicians and/or providers.

We suggest reviewing available plain films and MRI correlation preprocedure to avoid unnecessary radiation that occurs with doing this with live fluoroscopy. Often, practitioners will unnecessarily focus on the lumbar numbering (i.e., counting caudad from T12 and/or counting cephalad from the sacrum) instead of our recommendation of simply correlating the available imaging (i.e., the sagittal MRI and the lateral plain and fluoroscopic imaging). **It is imperative that the presence of the transitional segment is well communicated and documented so that all treating physicians/practitioners use the same enumeration terminology.**

Confirming the Correct Segment: A Technical Note

If the interventionalist remains uncertain as to which segment to target after preprocedural review of imaging studies, a much smaller "marker needle" (e.g., a 25- or 27-G, 1.5-inch needle) can be placed in the AP view at the segment that is believed to be the correct segment before switching to a lateral view to confirm that the correct segment has been identified. In doing so, the interventionalist can minimize trauma to the patient if the targeted segment turns out to be incorrect or advantageously anesthetize a soft tissue track for the injection should the targeted segment turn out to be the correct segment.

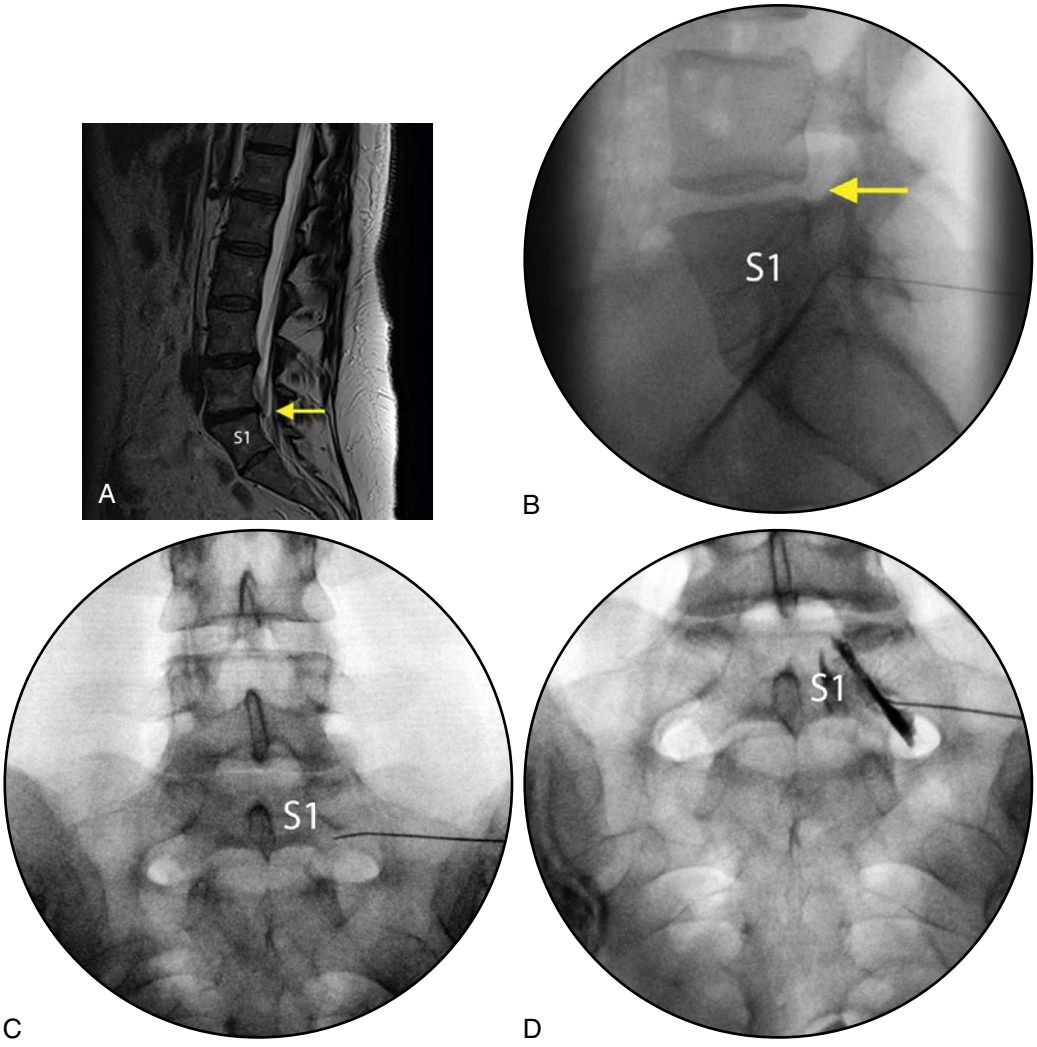

Fig. 3.8. A, T2-weighted sagittal magnetic resonance (MR) image of a patient with a transitional segment (**lumbarized S1**). In this case, the yellow arrow indicates the pathology of interest, an L5-S1 disc protrusion encroaching the traversing S1 nerve root. This patient has radicular pain in the S1 distribution and is to receive an S1 (S1-2) transforaminal epidural steroid injection. **B,** Fluoroscopic lateral view of the same patient with a lumbarized S1 transitional segment. The needle is in the S1 (S1-2) foramina, and the yellow arrow indicates the L5-S1 disc space. Note that the S1 (S1-2) foramen, because it is lumbarized, resembles that of the typical lumbar segments. The intent was to place medication along S1, with the contrast and medication directed superiorly toward the posterior L5-S1 disc. Without correlating MR and fluoroscopic images, an inexperienced interventionalist may have mistaken the segments and may not have addressed the intended level. **C,** Fluoroscopic anteroposterior (AP) view with the same needle approaching the S1 (S1-2) foramen. The lumbarized S1 transitional segment is labeled. **D,** Fluoroscopic AP view showing the flow of contrast outlining the S1 nerve root and exiting the spinal nerve.

Obtaining "True" Anteroposterior Views

"Treat the Patient, Not the Table"

Each segment is not necessarily aligned with the others as a result of normal anatomy (e.g., lordosis, kyphosis, etc.), pathology (e.g., lateral or rotary scoliosis, listhesis, etc.), positioning on the table, or some combination of these factors. To optimize the efficiency and safety of a procedure, **the proper positioning of the C-arm to obtain a "true" AP view of the targeted segment is recommended.** Note that if an oblique adjustment of the C-arm is required to obtain a "true" AP view, geometry dictates that a similar adjustment will be required to obtain a "true" lateral view (see Obtaining "True" Lateral Views, below).

Oblique the C-Arm to Optimize the "True" Anteroposterior View

The C-arm image intensifier is obliqued to obtain a "true" AP view relative to the specific segment being targeted, with the spinous process (SP) at the midline of the vertebral body and equidistant from each pedicle. Also note that in the "true" AP view, the left and right cortical borders of the SP should appear equally dense. The "true" AP view is not necessarily at 0 degrees of obliquity, as indicated on the fluoroscope. If the patient has multiple levels to be treated, a "true" AP should ideally be obtained at each segment being targeted (Fig. 3.9).

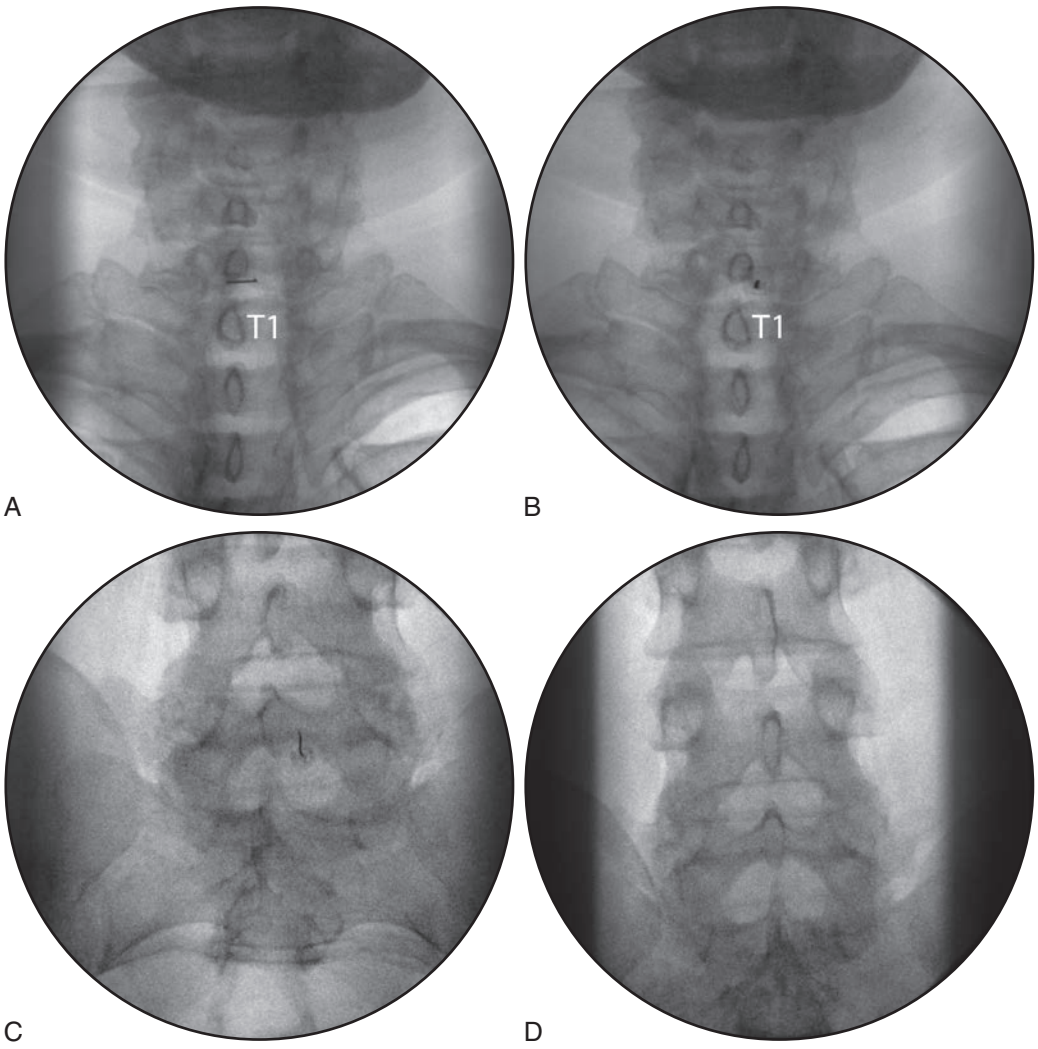

Fig. 3.9. A, Fluoroscopic anteroposterior (AP) view of the cervicothoracic spine with the T1 segment labeled and a needle tip at the inferior aspect of the C7 lamina. Notice the spinous process of T1 is not centered; therefore, T1 is not at "true" AP. **B,** By obliquing the C-arm leftward, toward the T1 spinous process, it is now centered (and the left and right cortical borders of the spinous process became equally dense) and is at "true" AP. Notice that this also affects C7 to a certain degree as its spinous process is now approaching the midline, but C7 is still not at "true" AP. This is because the vertebral segments are independent of one another and must be individually addressed. **C,** Fluoroscopic AP image of the L-spine with the needle tip at the L5 lamina. Note the spinous process of L5 is not centered (and the left cortical border of the spinous process is more dense than the right); therefore, L5 is not at "true" AP. **D,** By obliquing the C-arm leftward toward the L5 spinous process, it is now centered (and the left and right cortical borders of the spinous process are equally dense) and is at "true" AP. The needle, in this case, had since been withdrawn.

Tilt the C-Arm to Optimize the "True" Anteroposterior View

The vertebral body end plates, which are circumferentially bordered by the ring apophysis, cover both the superior and inferior horizontal surfaces of the vertebral body. Lining up the vertebral body end plates is an important skill for obtaining a clear and direct view of the target region for many procedures. For example, when performing discography, the trajectory view requires direct parallel visualization of the end plates. This fluoroscopic view is obtained with the cephalad or caudad tilt of the C-arm image intensifier. In this example, this optimizes the superior end plate of the inferior vertebral body, which is visualized as a solid horizontal line rather than as an ellipse (Fig. 3.10).

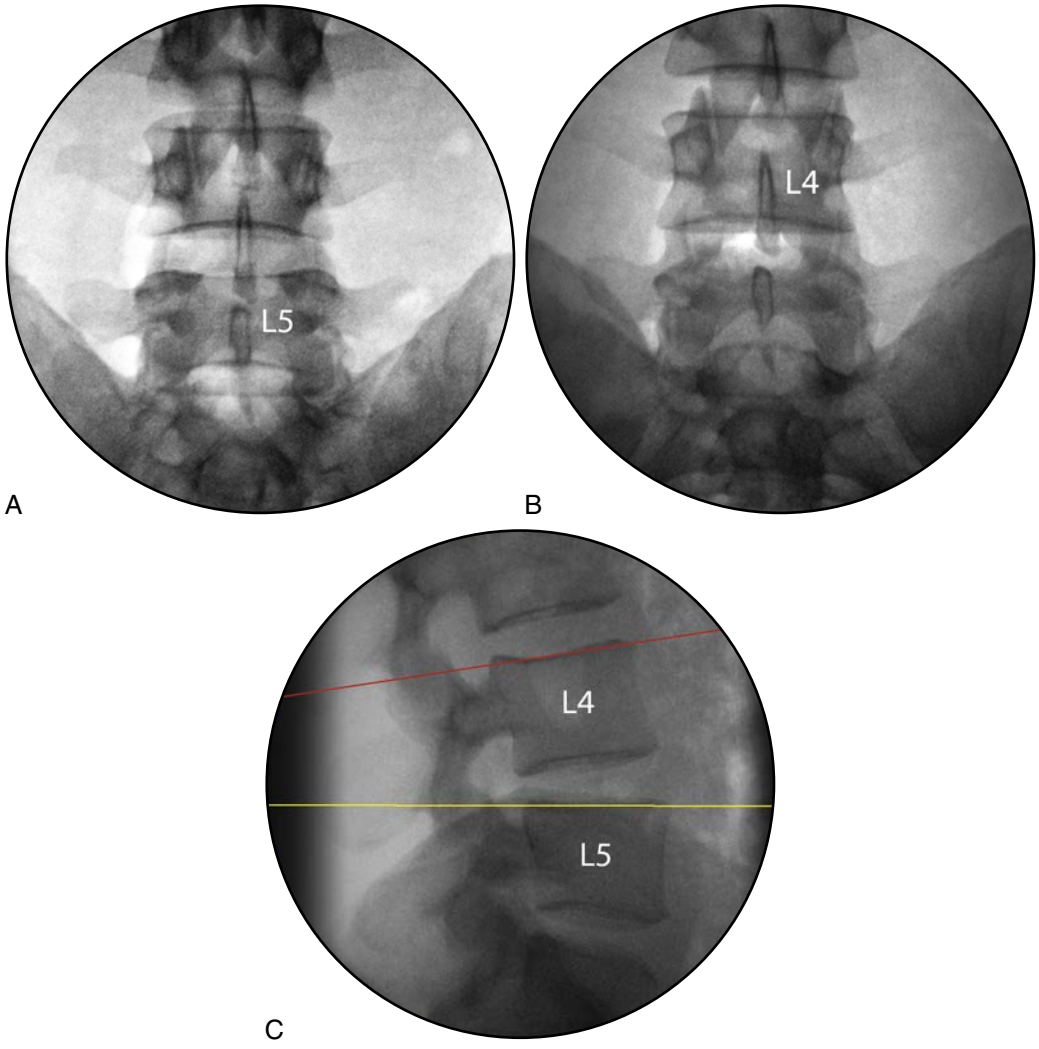

Fig. 3.10. A, Anteroposterior (AP) image of the L-spine with the superior end plate of L5 preferentially lined up. Note the more elliptical shape of the inferior end plate of L5 because the superior and inferior end plates of the vertebral bodies are usually not anatomically parallel to each other. The L4 end plates are clearly not lined up and also appear elliptical. **B,** An AP image of the same patient with the C-arm tilted to line up the superior end plate of L4. Note the more elliptical shape of the inferior end plate of L4 because the superior and inferior end plates of the vertebral bodies are usually not anatomically parallel to each other. The L5 end plates are now clearly not lined up because they appear elliptical. **C,** A lateral image of the same patient with the yellow line representing the projection of the beam through the superior end plate of L5 (corresponding to Fig. 3.10A) and the red line representing the projection of the beam through the superior end plate of L4 (corresponding to Fig. 3.10B). Note that tilting the C-arm is necessary to line up the superior end plate of L4 versus L5.

Obtaining “True” Lateral Views

As noted above, each segment is not necessarily aligned with the others as a result of the normal anatomy (e.g., lordosis and kyphosis), pathology (e.g., lateral or rotary scoliosis, and listhesis), positioning on the table, or some combination of these factors. To optimize the efficiency and safety of a procedure, the C-arm’s oblique and wig-wag (swivel) features should be used to obtain a “true” lateral view of the targeted segment.

Oblique the C-Arm to Optimize the “True” Lateral View

The C-arm should be obliqued 90 degrees from the angle at which the “true” AP view was obtained. The table may need to be laterally rotated to accommodate angles that cannot be obtained with the C-arm obliquely. When patients have multiple levels to be treated, the “true” lateral view should be ideally obtained for each respective level.

For the cervical spine, a “true” lateral view may be obtained by lining up the lateral masses. If the patient is prone or supine, this is accomplished with the use of the wig-wag feature and may require additional obliquing of the C-arm or table. If the patient is in a side-lying position, this is accomplished by tilting and occasional obliquing. Sometimes each segment must be lined up individually (Fig. 3.11; see also Chapter 4 for further discussion).

For the thoracic spine, a “true” lateral view may be obtained by lining up the posterior ribs (Fig. 3.12 and Table 3.2).

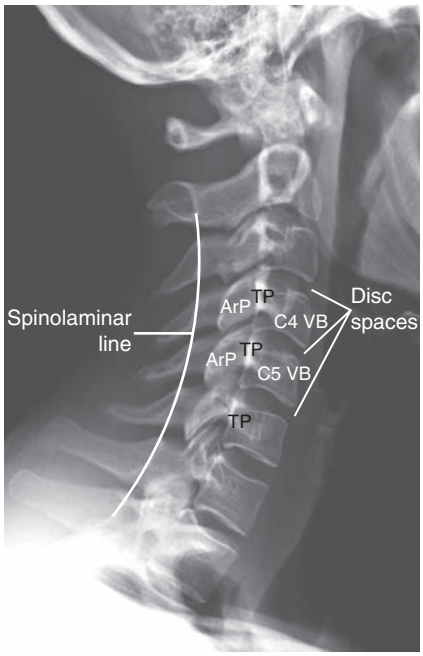

Fig. 3.11. Lateral C-Spine X-ray with C4 and C5 segmental levels optimally aligned. Use subtle changes in oblique, tilt, wig-wag, and/or patient positioning to optimize the targeted cervical segment. The C4 and C5 segments are optimized since they meet the criteria shown in Table 3-2. In contrast, the C3, C6, and C7 segments are not optimal laterals due to the ArP double borders and diminished distance between the posterior margin of the ArPs and spinolaminar lines.

Table 3-2 Optimal C-spine lateral Criteria (Modified From Ref #4-SIS Guidelines)

- Disc spaces are clear without superimposed bony shadows.
- Transverse processes (TP) occupy the posterior superior corner of the vertebral body (VB).
- Articular pillars (ArPs) are superimposed (no double borders).
- ArPs subdivide the anterior to posterior canal width by about half.
- There is maximized space between the ArP posterior margin and spinolaminar line.

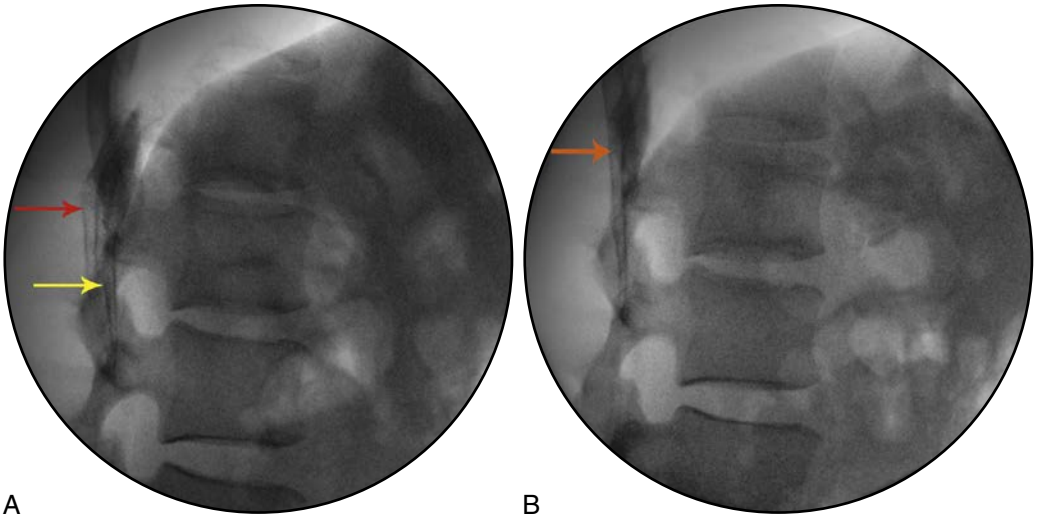

Fig. 3.12. A, A lateral image of the thoracic spine. Note that the spinolaminar line is vague, and the posterior ribs *(red and yellow arrows)* are not superimposed. **B,** A "true" lateral image of the thoracic spine acquired by obliquing the C-arm to superimpose the posterior ribs *(orange arrow)*.

The lateral view is obtained by obliquing the C-arm 90 degrees from the true AP view.

For the lumbar spine, a "true" lateral view can be obtained by superimposing the pelvic (iliopectineal) lines at the lumbosacral junction and/or by squaring the end plates for each respective lumbar segment (Fig. 3.13). (Wig-wag may also be necessary and will be discussed below.)

Wig-Wag the C-Arm to Optimize the "True" Lateral View

The C-arm image intensifier can also be wig-wagged to obtain a "true" lateral view with the vertebral body end plates lined up. (This is analogous to a cephalad or caudad tilt in the lateral side-lying position, as described in the following section.) In addition, the wig-wag feature can be used to line up the pelvic (iliopectineal) lines at the S1 level. If the patient has multiple levels to be treated, the "true" lateral view should be ideally obtained each time for the corresponding level (Fig. 3.14).

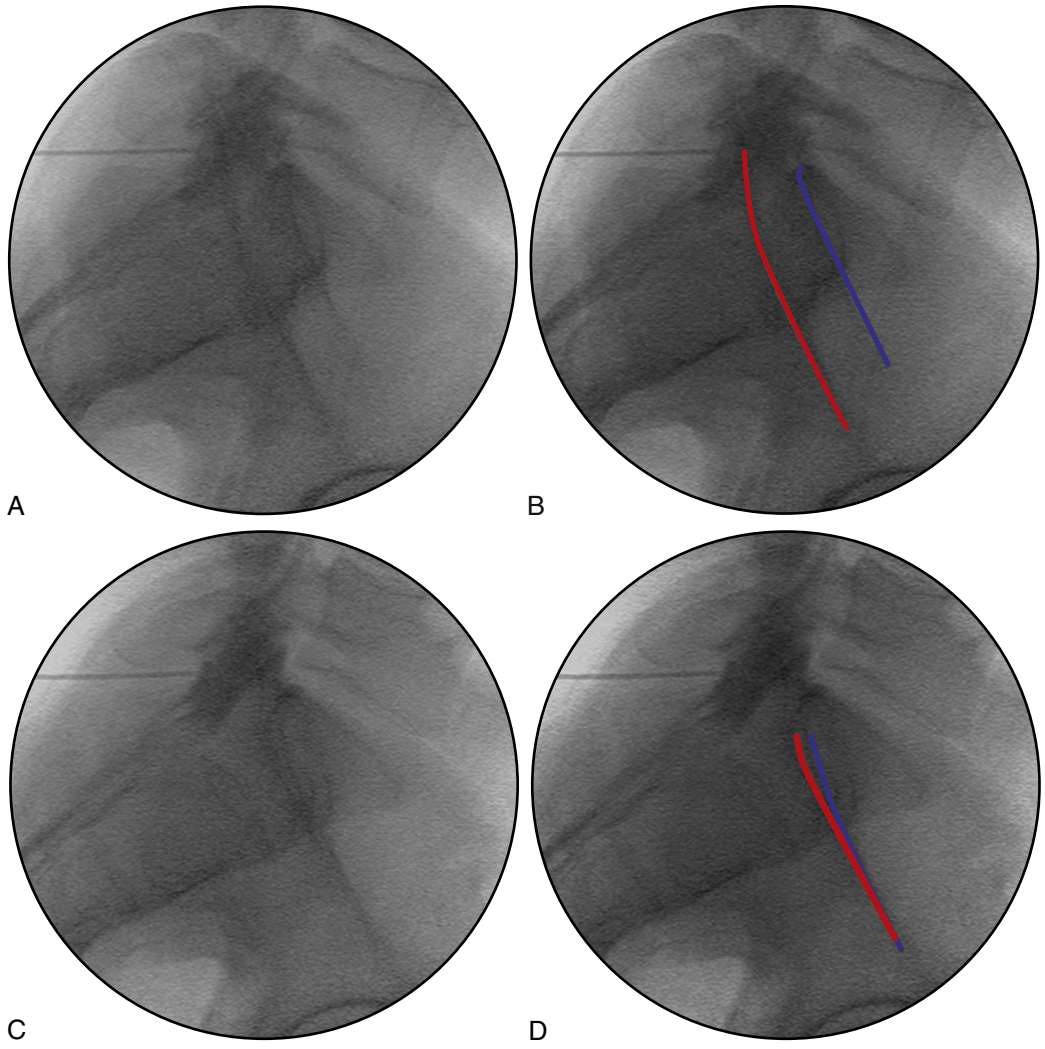

Fig. 3.13. A, Fluoroscopic lateral image of a patient with scoliosis, with the pelvic (iliopectineal) lines not lined up at the S1 vertebral segment. **B,** Fluoroscopic lateral image of the same patient, with the pelvic (iliopectineal lines) outlined in red and blue. For the lumbar spine, a "true" lateral image is more difficult to confirm with obliquing, because the landmarks are not as evident. **C,** In the same patient, the C-arm is then obliqued slightly less to obtain a "true" lateral view of the pelvic (iliopectineal) lines at the S1 vertebral segment. **D,** The overlapping pelvic (iliopectineal) lines are indicated in blue and red.

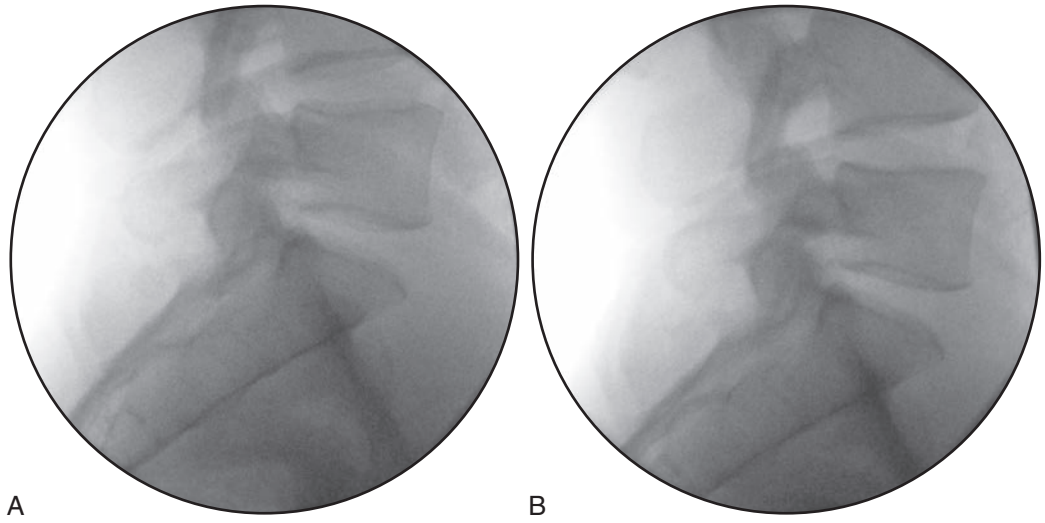

Fig. 3.14. A, Fluoroscopic lateral image of the L-spine, with the L5 vertebral body's superior and inferior end plates poorly lined up. Note the elliptical shape of both superior and inferior end plates of L5 and the pelvic (iliopectineal) lines are not optimally superimposed. **B,** Fluoroscopic lateral image of the same patient, with the superior end plate of L5 preferentially lined up with the use of the C-arm wig-wag. In this case, but not necessarily so, the pelvic (iliopectineal) lines are optimally superimposed.

Patient in a Side-Lying Position

As alluded in the previous section, when a patient is in a side-lying position (i.e., cervical medial branch blocks), the same techniques are used to optimize the fluoroscopic image. However, with the patient in a side-lying position, the wig-wag maneuver accomplishes the same as a cephalad-caudad tilt would for a patient in the prone or supine position; the oblique remains the oblique, and the cephalad-caudad tilt becomes the wig-wag maneuver (Table 3.1, Fig. 3.15).

Fig. 3.15. Simulated patient in a side-lying position. Note the C-arm is in an anteroposterior position relative to the patient. A clockwise wig-wag (shown) is equivalent to a caudad tilt (Fig. 3.3B) in a patient in the prone position. (See Table 3.3.)

Table 3.3 C-Arm Movements Used to Optimize Structure Visualization*

	C-Arm Left-Right	C-Arm Cephalad-Caudad	C-Arm 3rd Axis
Prone or supine	Oblique	Tilt	Wig-wag
Side-lying	Oblique	Wig-wag	Tilt

*Note that the tilt and wig-wag use changes when the patient is side-lying.

Oblique Views

Oblique imaging will optimize visualization of different structures. When we optimize cervical neural foramina visualization (to either target or avoid them), we describe the foraminal oblique view. When we are focusing on other structures such as the lamina or lateral pillars/cervical Z-joints, we will describe either ipsilateral or contralateral oblique (CLO) views depending on the image intensifier's position relative to the structure.

Foraminal Oblique (Cervical Spine) View

In addition to the standard views (i.e., the "true" AP and lateral views), the foraminal oblique view provides an additional orientation that can be used to guide or confirm needle placement for many cervical procedures where the neural foramina are either targeted (transforaminal injection) or avoided (neurotomy) (Figs. 3.16 to 3.19). The view can be utilized regardless of whether the patient is in the supine, prone, or side-lying position. The foraminal oblique view is obtained by aligning the fluoroscopic beam parallel to the neural foramen's oblique orientation (approximately 45 degrees). This underused technique can help with the visualization of cervical facet joints or articular pillars, which may otherwise be poorly visualized (e.g., obscured by the shoulders). **The key concept of the foraminal oblique view is to orient the neural foramen ipsilateral to the treatment side regardless of the position of the patient.** The zygapophysial joint and its associated medial branches of interest are located dorsal to the neural foramen. In the examples shown later in Figs. 3.17 to 3.19, the simulated procedures are all performed on the left side; therefore, the left-sided foramina are visualized. For a cervical transforaminal ESI, the tilt is used to optimize left-sided foramina visualization. For cervical Z-joint procedures, the tilt is used to optimize Z-joint and articular pillar visualization.

Fig. 3.16. Spine model; posterior is the right side of the picture. Note the angle of the posteriorly located left zygapophysial joint compared with that of the anteriorly located left neural foramen. The zygapophysial joint is angled approximately 25 to 35 degrees caudad. The neural foramen is angled approximately 45 degrees oblique and 10 to 25 degrees caudad. The association of these angles to one another determines the direction of tilt and/or oblique that is required to optimally visualize either the zygapophysial joint or neural foramen.

Fig. 3.17. A, With the simulated patient in the supine position, the fluoroscope is obliqued 45 degrees in the ipsilateral direction to obtain the left foraminal oblique view. To optimize the visualization of the neural foramen in this foraminal oblique view as in cervical TF-ESIs, the image intensifier is tilted in the caudad direction. **B,** Fluoroscopic image corresponding to Fig. 3.17A. The left cervical neural foramina are optimally visualized. This imaging would be used for a cervical transforaminal injection. **C,** With the patient in the supine position, the fluoroscope is obliqued 45 degrees in the ipsilateral direction to obtain the left foraminal oblique view. To optimize the visualization of the zygapophysial joints and articular pillars in this foraminal oblique view, the image intensifier is tilted in the cephalad direction. **D,** Fluoroscopic image corresponding to Fig. 3.17C. The left cervical Z-joints and associated articular pillars are optimally visualized. This imaging would be used for cervical Z-joint intraarticular or medial branch procedures. Note that the setup of the C-arm relative to the patient (C) and fluoroscopic imaging (D) are similar to those in Figs. 3.18 and 3.19.

Fig. 3.18. A, With the simulated patient in the prone position, the fluoroscope is obliqued 45 degrees in the contralateral (contralateral oblique) direction to visualize the left neural foramen (foraminal oblique view). In this picture, the left-sided Z-joints are targeted (needle not shown) and the C-arm is obliqued toward the right. To further optimize the visualization of the left zygapophysial joint in this contralateral oblique/foraminal view, the image intensifier is tilted in the caudad direction in line with the Z-joints' and articular pillars' orientation. **B,** Fluoroscopic image corresponding to Fig. 3.18A. The left cervical Z-joints and associated articular pillars are optimally visualized. This imaging would be used for cervical Z-joint intraarticular or medial branch procedures. Note that the setup of the C-arm relative to the simulated patient (A) and fluoroscopic imaging (B) are similar to those in Figs. 3.17 and 3.19. Because cervical transforaminal injections are not performed for a patient in the prone position, we are not demonstrating the optimal visualization of the neural foramen in the prone foraminal oblique view.

Fig. 3.19. A, With the simulated patient in the right lateral decubitus position, treating the left side, the fluoroscope is obliqued 45 degrees in the ipsilateral direction to obtain the left foraminal oblique view. To further optimize the visualization of the neural foramen in the foraminal oblique view, the image intensifier is tilted in the caudad direction. **B,** Fluoroscopic image corresponding to Fig. 3.19A. The left cervical neural foramina are optimally visualized. This imaging could be used for a cervical transforaminal injection, however, this is just shown to demonstrate foramina visualization optimization. We do not recommend using this patient positioning for a cervical tf-esi. **C,** With the patient in the right lateral decubitus position, the fluoroscope is obliqued 45 degrees in the ipsilateral direction to obtain the left foraminal oblique view. To optimize the visualization of the zygapophysial joints and articular pillars in this ipsilateral oblique/foraminal view, the image intensifier is tilted in the cephalad direction. **D,** Fluoroscopic image corresponding to Fig. 3.19C. The left cervical Z-joints and associated articular pillars are optimally visualized. This imaging would be used for cervical Z-joint intraarticular or medial branch procedures. Note that the setup of the C-arm relative to the patient (C) and fluoroscopic imaging (D) are similar to those in Figs. 3.17 and 3.18.

The "Scotty Dog" in Lumbar Oblique Projections

Fig. 3.20 demonstrates the "Scotty dog," which is often used in lumbar oblique projections to assist in lumbar landmark identification.

- Pedicle (P) — eye
- Transverse process (TP) — nose
- Pars interarticularis (PI) — neck
- Inferior articular process (IAP) — front and rear legs
- Superior articular process (SAP) — ear
- Spinous process (SP) — tail
- Lamina (Lam) — body

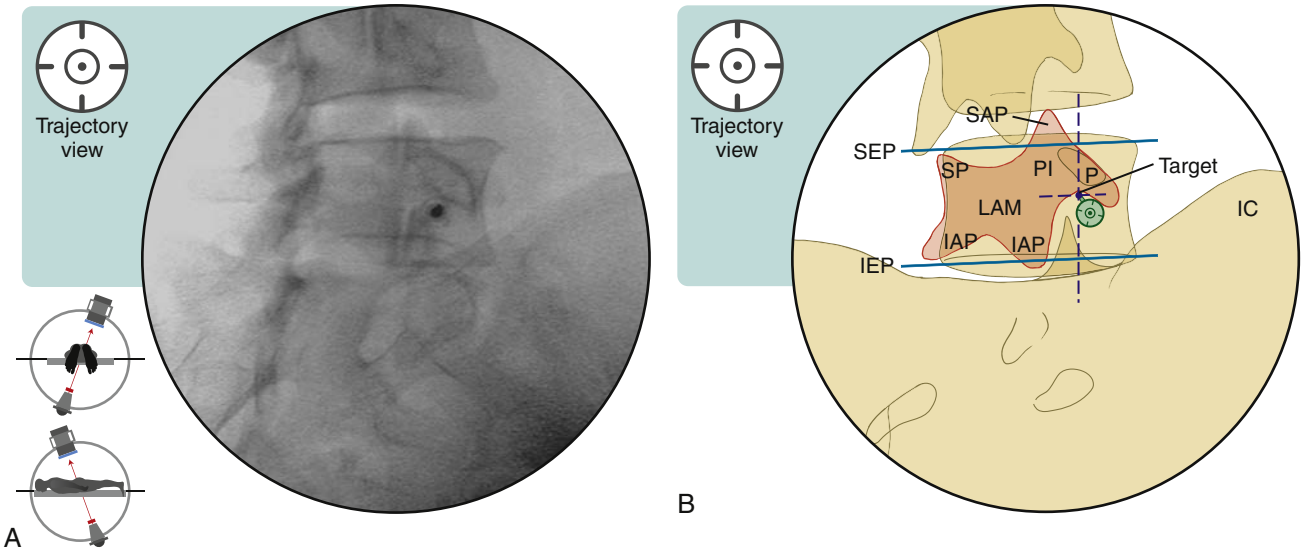

Fig. 3.20. The "Scotty dog" in lumbar oblique projections to assist in identifying fluoroscopic lumbar landmarks. **A,** Fluoroscopic image with needle in position for a supraneural transforaminal epidural steroid injection (TF-ESI) (see Chapter 13). **B,** Corresponding radiopaque structures identified with "Scotty dog" components. Note how the lumbar spine anatomic landmarks create the "Scotty dog" outline and eye: transverse process (TP) — nose, pars interarticularis (PI) — neck, inferior articular process (IAP) — front and rear legs, superior articular process (SAP) — ear, spinous process (SP) — tail, lamina (Lam) — body, pedicle (P) - eye.

Contralateral Oblique View to Visualize the Ventral Aspect of the Lamina

The spinolaminar line can be best visualized in the lateral view. The lateral view appreciates the junction where the lamina and SP intersect but does not demonstrate the ventral aspect of the lamina, which is obscured in this view by the body of the lamina itself. In the CLO view, the laminae are seen in the cross-section, appearing dense and uniformly elliptical.[5-7] In this view, one can clearly visualize the ventral and dorsal cortices of each lamina (Figs. 3.21 to 3.24). A "true" CLO view requires the dorsal and ventral cortices of the lamina to be of equal density (isointense). The ventral interlaminar line is a line interconnecting the ventral aspects of the lamina, with the dorsal epidural space lying just anterior to it (Fig 3.21).

This view is mostly used for lumbar, thoracic, and cervical interlaminar epidural steroid injections (ESIs) and spinal cord stimulation lead placement (see Chapters 12, 18, 20, 25, and 26). Figs. 3.22, 3.23, and 3.24 show cervical, thoracic, and lumbar CLO views, respectively.

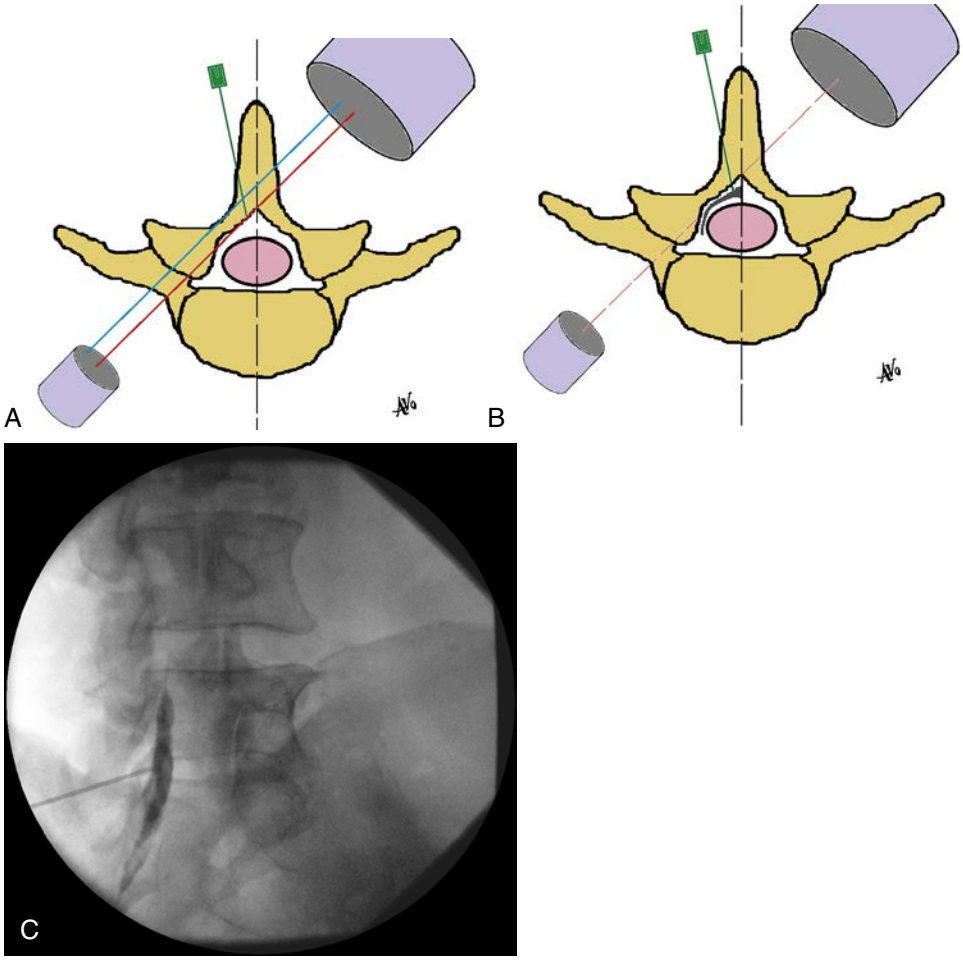

Fig. 3.21. A, An axial view of a vertebral segment with a simulated interlaminar epidural steroid injection. The C-arm is obliqued contralateral to the needle tip. The oval within the canal represents the thecal/dural sac surrounding the spinal cord and/or descending nerve roots. The fluoroscopic beam projects perpendicular to the needle and parallel to the contralateral lamina including its ventral aspect (red line). The line connecting adjacent ventral lamina represents the ventral interlaminar line (VILL). The blue line represents the dorsal aspect of the lamina. **B,** The needle tip is carefully advanced beyond the VILL and the ligamentum flavum (not pictured) into the epidural space. Contrast flow (gray) is noted in the epidural space on the side of the needle. A thick contrast line will be seen. **C,** Corresponding oblique fluoroscopic image corresponding to **B**. Note the thick contrast line seen ventral to the VILL.

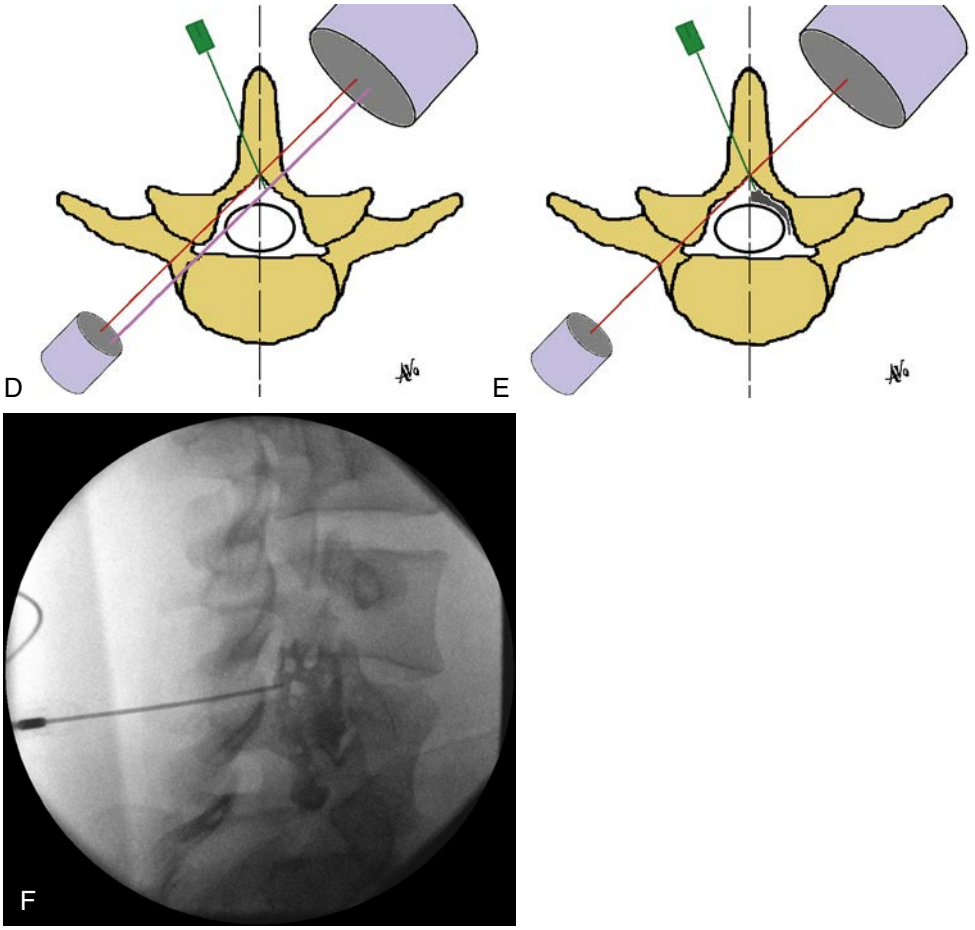

Fig. 3.21, cont'd D, If the tip of the needle crosses midline (whether intentionally or unintentionally) it will also have passed beyond the visualized contralateral VILL, but in this case, may have an appearance that is "too deep" with respect to the VILL (red line). The purple line represents the depth of the tip of needle. **E,** The tip of the needle had been advanced across midline with contrast flow in the epidural space on the opposite side of the needle. An amorphous contrast pattern will be seen. **F,** Corresponding oblique fluoroscopic image corresponding to **E**. Note the amorphous contrast pattern seen ventral to the VILL. More interlaminar epidural fluoroscopic images and contrast patterns can be seen in Chapters 12 (Lumbar), 20 (Thoracic), and 25 (Cervical).

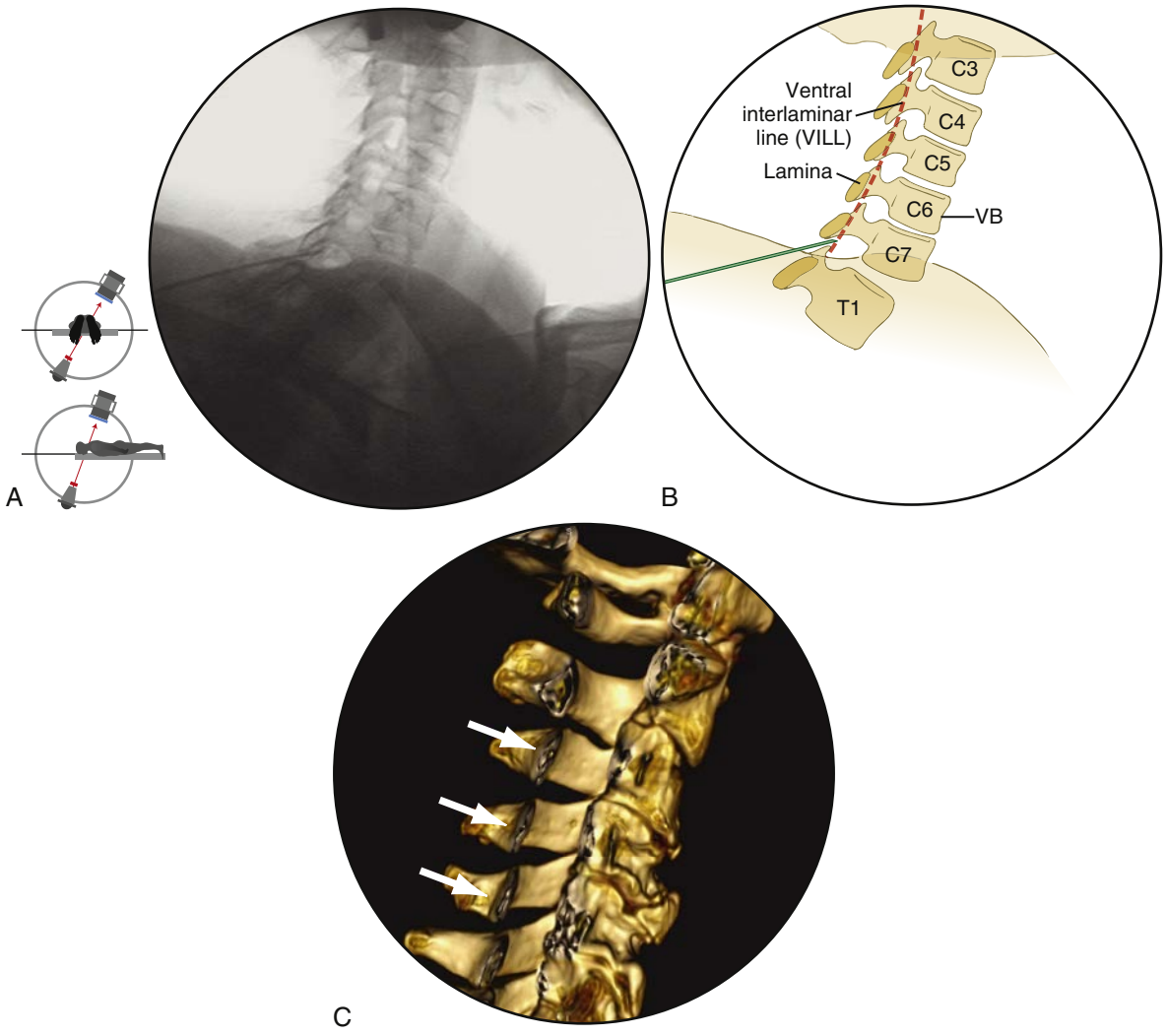

Fig. 3.22. A, Fluoroscopic contralateral oblique view of the cervical spine during a C7-T1 interlaminar epidural steroid injection. **B,** Diagram of radiopaque cervical structures seen in Fig. 3.22A. The outlined elliptical structures represent the lamina. Notice the needle in association with the lamina and VILL. **C,** Three-dimensional computed tomography reconstruction of a cut away cervical spine. The elliptical lamina shown in the contralateral oblique fluoroscopic view (Fig. 3.22A) corresponds with the cross-section of the lamina on the computed tomography reconstruction *(arrows)*.

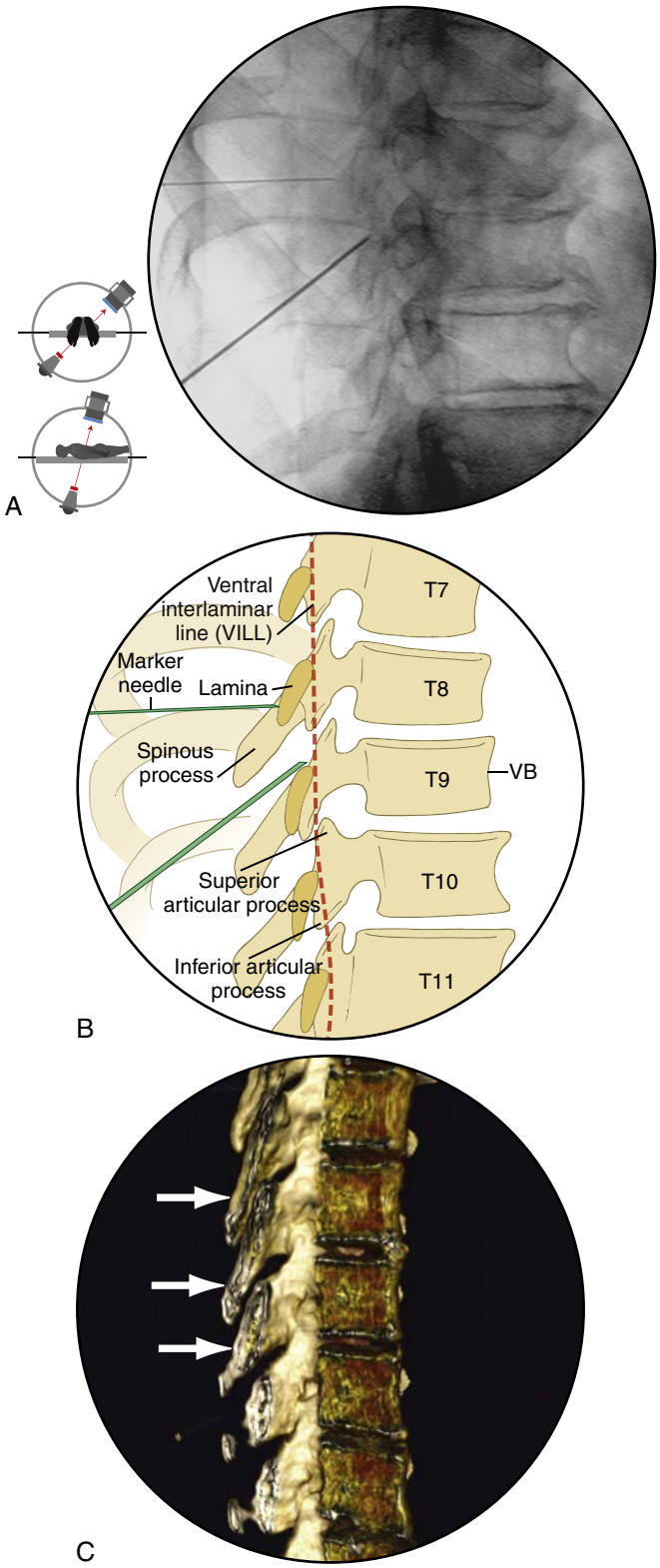

Fig. 3.23. A, Fluoroscopic contralateral oblique view of the thoracic spine during a T8-T9 interlaminar epidural steroid injection. **B,** Diagram of radiopaque thoracic structures seen in Fig. 3.23A. The outlined elliptical structures represent the lamina. Notice the needle in association with the lamina and VILL. **C,** Three-dimensional computed tomography reconstruction of a cut away thoracic spine. The elliptical lamina shown in the contralateral oblique fluoroscopic view (Fig. 3.23A) corresponds with the cross-section of the lamina on the computed tomography reconstruction *(arrows)*.

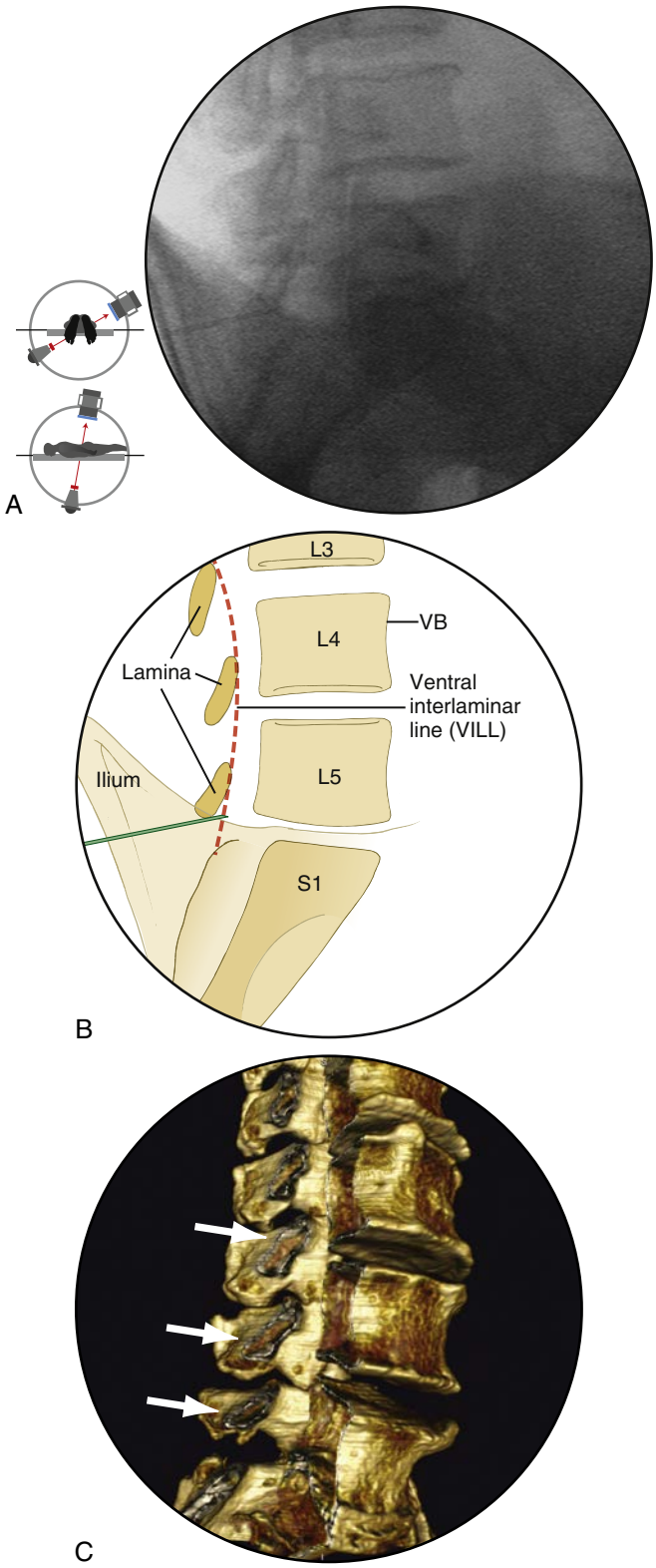

Fig. 3.24. A, Fluoroscopic contralateral oblique view of the lumbosacral spine during an L5-S1 interlaminar epidural steroid injection with a needle in the L5-S1 interlaminar space. **B,** Diagram of radiopaque lumbosacral structures seen in Fig. 3.24A. The darker elliptical structures represent the lamina. Notice the needle in association with the lamina and VILL. **C,** Three-dimensional computed tomography reconstruction of a cut away lumbar spine. The elliptical lamina shown in the contralateral oblique fluoroscopic view (Fig. 3.24A) corresponds with the cross-section of the lamina on the computed tomography reconstruction *(arrows)*.

Contralateral Oblique View Versus Lateral View

Most fluoroscopic procedures are performed using multiplanar views. For those that typically require AP and lateral views (e.g., cervical, thoracic, and lumbar interlaminar ESIs, as well as cervical and thoracolumbar spinal cord stimulation), there are some distinct advantages that the CLO view offers over the traditional lateral view.[5]

The CLO view offers superior visualization of the anatomy of interest, usually with better visualization than a lateral or AP projection. In the cervical spine lateral view, the lower cervical segments may be obscured by the shoulders. In the lumbar spine lateral view, the segments may be obscured by soft tissues. In the thoracic AP view, the space between the superior and inferior lamina is often difficult to visualize. The CLO view frequently improves target visualization in all of these cases.

In the lateral view, if the needle projection is not directly midline, the tip of the needle may falsely appear too deep. In this scenario, the interventionalist can redirect the needle, start over, or use the CLO view.

The CLO view offers a more accurate association between the tip of the needle and the ventral aspect of the lamina when the needle projection is off midline, as in interlaminar ESI using the paramedian approach (Fig. 3.24). Note that a "true" CLO view requires that the dorsal and ventral aspect of the lamina be of equal density (isointense).

In the CLO view, if the needle projection is off midline and the needle tip appears too deep, yet the target has still not been reached, the interventionalist can oblique the C-arm further contralateral and the needle tip will (appear to) move posteriorly toward the ventral aspect of the lamina.

In the event that the needle crosses the midline, the needle tip on the CLO view will also falsely appear too deep. In this scenario, the interventionalist can oblique the C-arm ipsilaterally toward the side of the needle shaft (away from the tip), and the association between the needle tip and ventral aspect of the (now) contralateral lamina will be accurate again.

If the interventionalist has difficulty recognizing or entering the interlaminar space in the AP or lateral view, the CLO view can demonstrate the needle tip approaching (or contacting) the superior or inferior lamina while also providing clear visual feedback on depth, thus helping to avoid unnecessary needle trauma to the patient.

Optimizing Needle Trajectory

Once the level is confirmed and the fluoroscopic trajectory view is optimized, we introduce the needle through the sterilized and anesthetized skin following the trajectory of the fluoroscopic beam ("down the beam"). If the needle is not parallel to this trajectory, the image will not be optimal and the needle trajectory will need to be corrected before it is advanced further (Fig. 3.25).

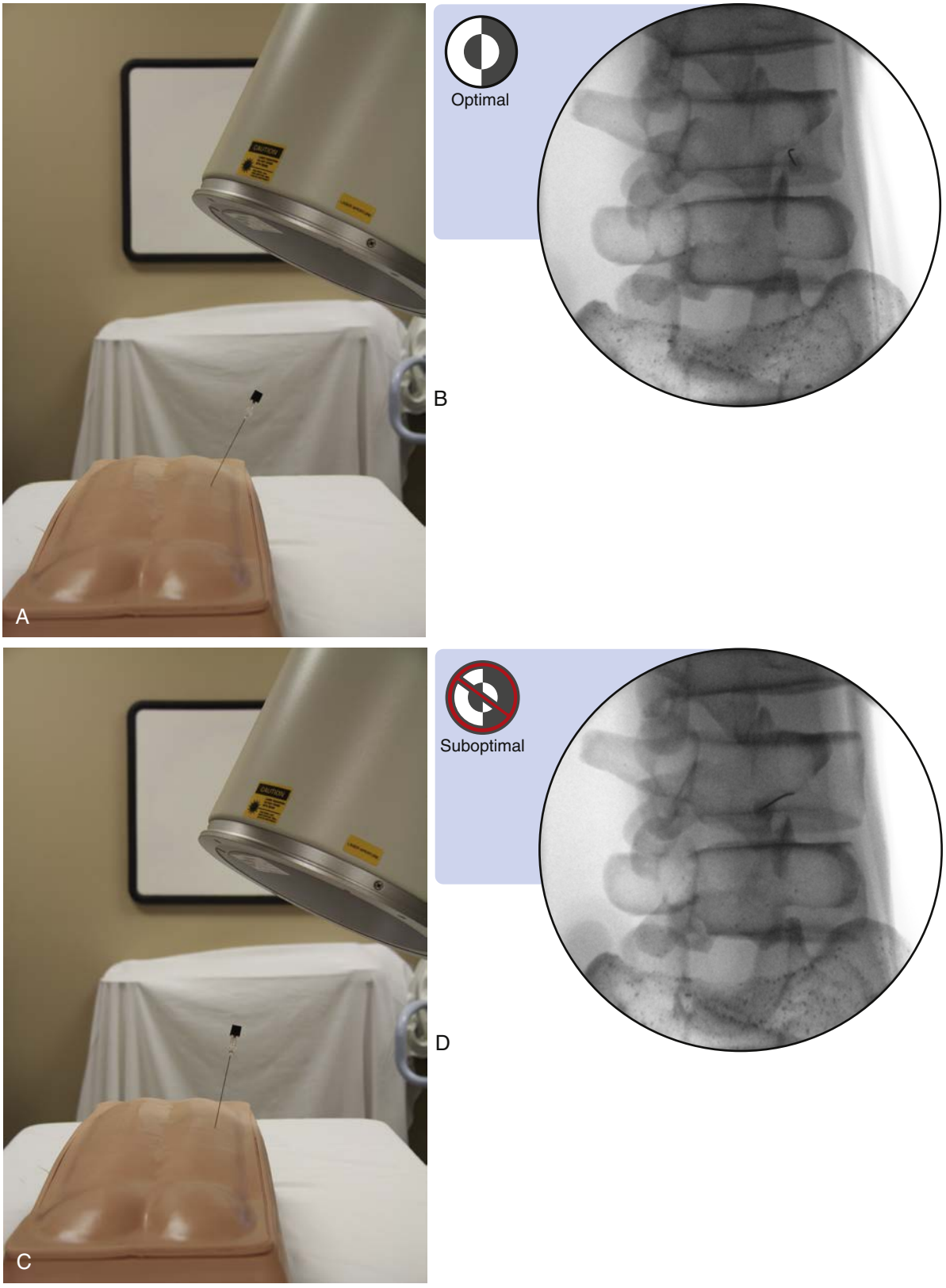

Fig. 3.25. A, An image demonstrating that the needle trajectory is parallel with or "down the beam" of the C-arm during a simulated lumbar transforaminal epidural steroid injection. **B,** Fluoroscopic image corresponding to Fig. 3.25A. The needle's trajectory is parallel to that of the C-arm's trajectory toward the intended right L4 transforaminal space. Note the needle shaft is barely visible as it is being directed parallel to the beam. **C,** An image demonstrating that the needle trajectory is not parallel with or "down the beam" of the C-arm. Note that the needle hub is obliqued left relative to the beam. **D,** Fluoroscopic image corresponding to Fig. 3.25C. Despite the initial needle tip being at the simulated right L4 transforaminal space, without correction, this path will lead to a destination too far lateral to the intended destination. Note that the needle shaft is more visible than that observed in Fig. 3.25B because the needle is not oriented parallel to the C-arm.

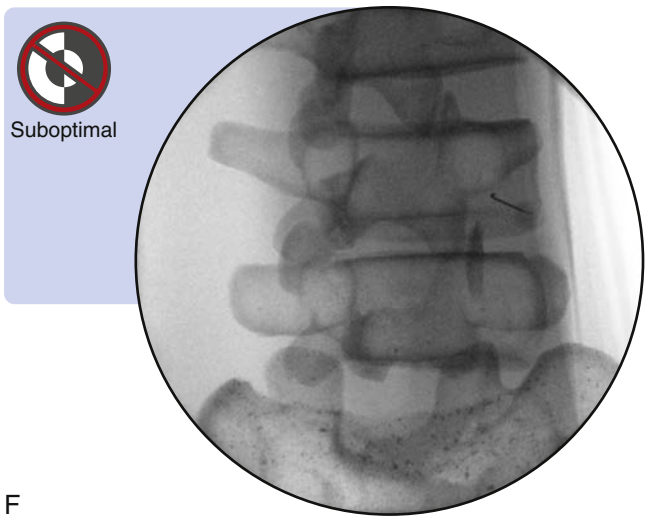

Fig. 3.25 cont'd E, An image demonstrating that the needle trajectory is not parallel with or "down the beam" of the C-arm. Note that the needle hub is obliqued right relative to the beam. **F,** Fluoroscopic image corresponding to Fig. 3.25E. Despite the initial needle tip being at the right L4 transforaminal space, without correction, this path will lead to a destination too far medial, either contacting bony structures (pedicle, pars, lamina, or Z-joint) or risking subdural/intrathecal penetration. Note that the needle shaft is more visible than that observed in Fig. 3.25B because the needle is not oriented parallel to the beam.

Parallax

Parallax is defined as the apparent (but not true) change in the position, size, or shape of an object as a result of an incorrect viewing angle (Fig. 3.26). Therefore, parallax is a distorted representation of an object on a fluoroscopic image. The danger of parallax is that a fluoroscopic image can misrepresent anatomy or the true location of the needle. Parallax can be minimized by positioning the object of interest (the target) in the center of the screen. Working with the target in the middle of the screen helps to align the image. As illustrated in Fig. 3.26B, the fluoroscopic beam is cone shaped as it travels from the image source to the image intensifier. Objects in the middle of the beam are seen "down the beam," whereas those on the edge appear distorted as a result of the beam's angle on the edges (Fig. 3.27).

Magnification

Magnification increases the apparent size of a structure represented in the fluoroscopic image. There are two methods for accomplishing magnification: electronic and geometric. Electronic magnification is a feature on C-arms that can be initiated via the control panel. On many C-arms, electronic magnification increases radiation emitted and decreases detail. In contrast, geometric magnification is related to the distance of the structure from the image source and image intensifier. When the image intensifier is moved closer to the structure (image source is moved away from the structure), the field of view increases and the structure will be less magnified (Fig. 3.26D). When the image source is positioned closer to the structure, the field of view decreases, and the structure will appear more magnified (Fig. 3.26C). As a result of a closer proximity to the image source, the skin entry dose and scatter become greater, increasing the patient's radiation dose and decreasing image quality.

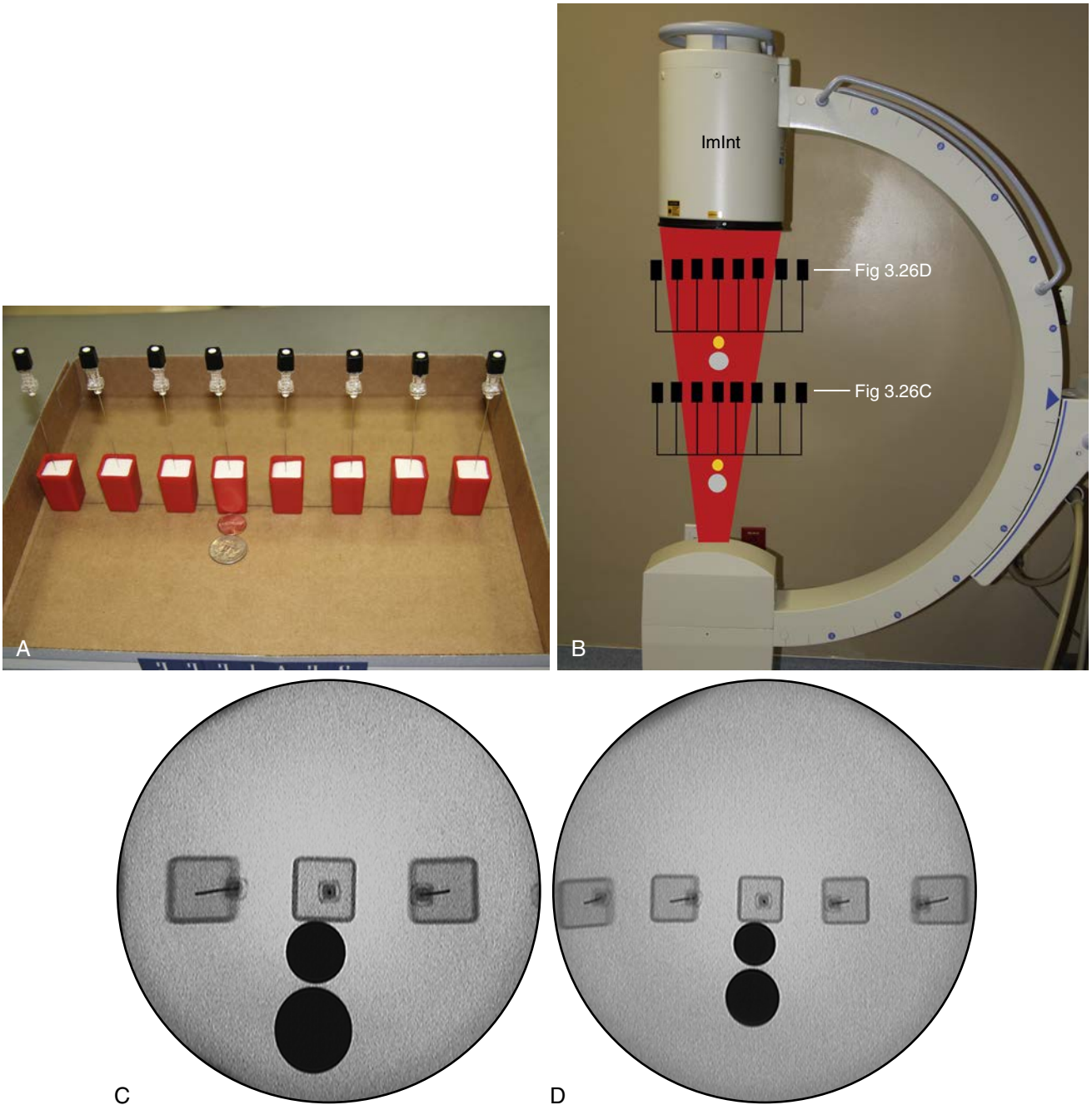

Fig. 3.26. A, Model of eight needles used to demonstrate parallax and magnification. Note that the needles are parallel to one another. A penny (copper) and quarter (silver) are shown for size reference. **B,** Cone-shaped fluoroscopic beam (in red) from the image source to the image intensifier (ImInt). Drawing of the eight needles (black) and coins (copper penny, silver quarter) also demonstrates less magnification as these objects approach the larger diameter image intensifier. Note that only the center needle and coins remained directly "down the beam." **C,** Fluoroscopic image of the same model shown in Fig. 3.26A. The needle in the center of the screen appears "down the beam" and shows an appropriate trajectory view. However, the needles at the edge of the screen appear to be approaching at an angle with the hubs oriented to the middle of the screen, when in fact the needles and hubs are all parallel to one another. **D,** The image intensifier and model are now closer so more of the needles are captured within the red beam. Since more needles are seen, the model's fluoroscopic image is less magnified. Furthermore, the needles at the edge of the screen appear to be approaching at an angle with the hubs oriented to the middle of the screen, when in fact the needles and hubs are all parallel to one another. Notice the images of the coins are smaller (less magnified) relative to the coins in Fig. 3.26C.

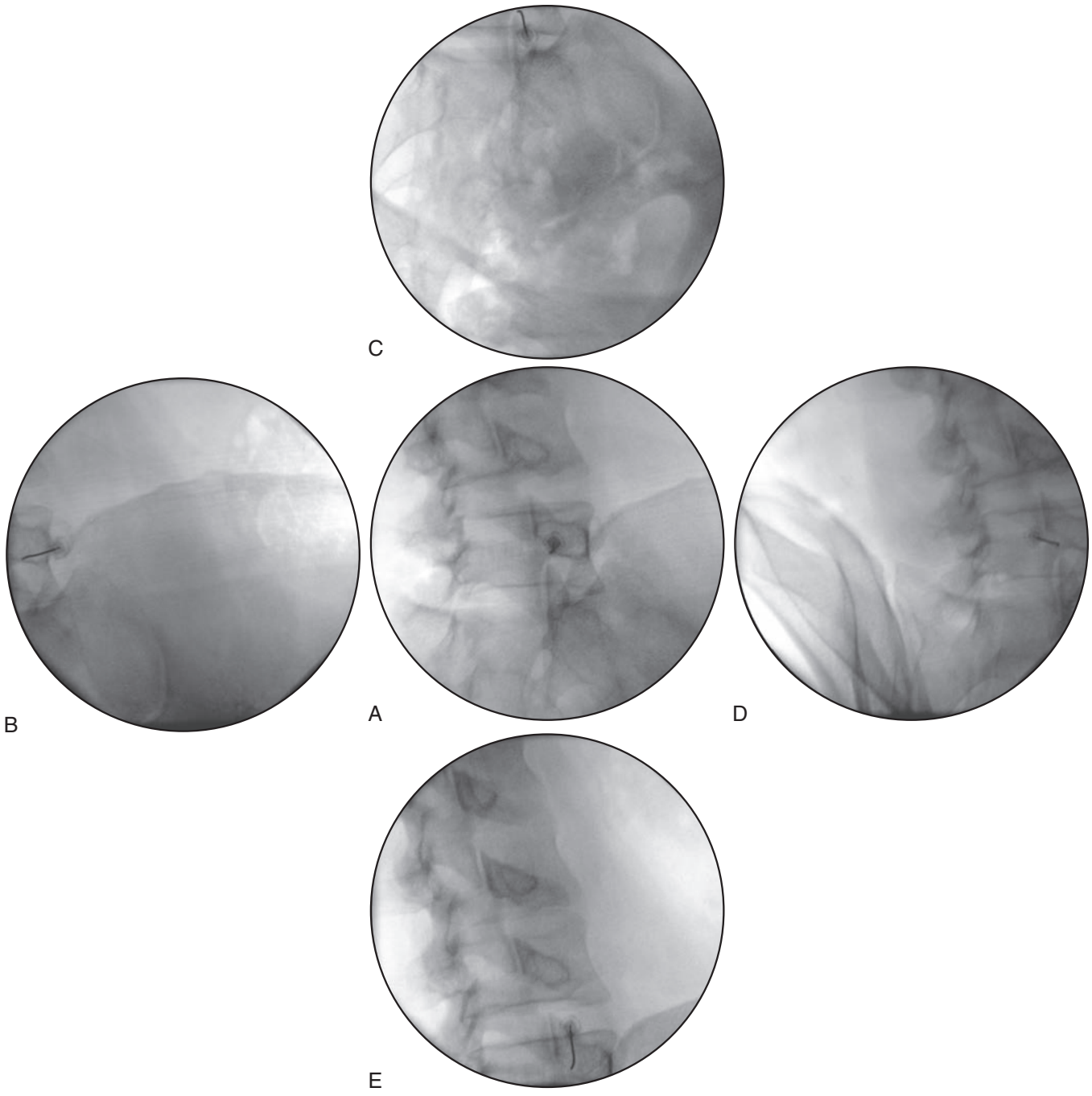

Fig. 3.27. Fluoroscopic images with the working environment at the center (**A**) and each edge (**B–E**) of the fluoroscopic beam. Note that each picture was taken by only translating the C-arm relative to the needle without a change in the C-arm's oblique or tilt orientation. There was no adjustment of the needle position. Because of parallax, the needle appears to be approaching the patient from different angles. The most accurate imaging occurs with the needle at the center of the screen (A).

"Tuning" an Oblique View for Optimal Needle Trajectory

As discussed in Chapter 1, in this book, specific angles are typically not provided for most procedures. Each patient, each segment, and often each side will have different anatomy. The anatomy dictates the setup, which will dictate the needle trajectory. However, in certain instances (e.g., CLO for cervical ESI and ipsilateral oblique for lumbar radiofrequency), we may suggest some starting angles.

Variations in anatomic alignment such as lordosis, scoliosis, and listhesis may pose challenges to the interventionalist when he or she is attempting to plan optimal needle trajectory. Although an optimal image may be visualized in the AP (or posteroanterior) view, this image may be suboptimal when the fluoroscope is positioned in the oblique view. An appreciation of the anatomic geometry will assist the interventionalist to safely and efficiently obtain an optimal trajectory view, thereby sparing unnecessary radiation exposure and decreasing the patient's procedure time.

Although elementary, it is important to appreciate that tilting the image intensifier will add a cephalad or caudad vector to the needle trajectory in the oblique view. For the patient with scoliosis who is undergoing a procedure with a trajectory view in oblique (i.e., medial branch blocks, transforaminal ESIs, and zygapophysial joint injections), the optimal view in AP may not produce an optimal trajectory to the target. Additional cephalad or caudad tilt may be required to compensate for lateral scoliosis (Fig. 3.28). The oblique and tilt required to obtain the optimal trajectory view will typically vary not only for each level but also for each side.

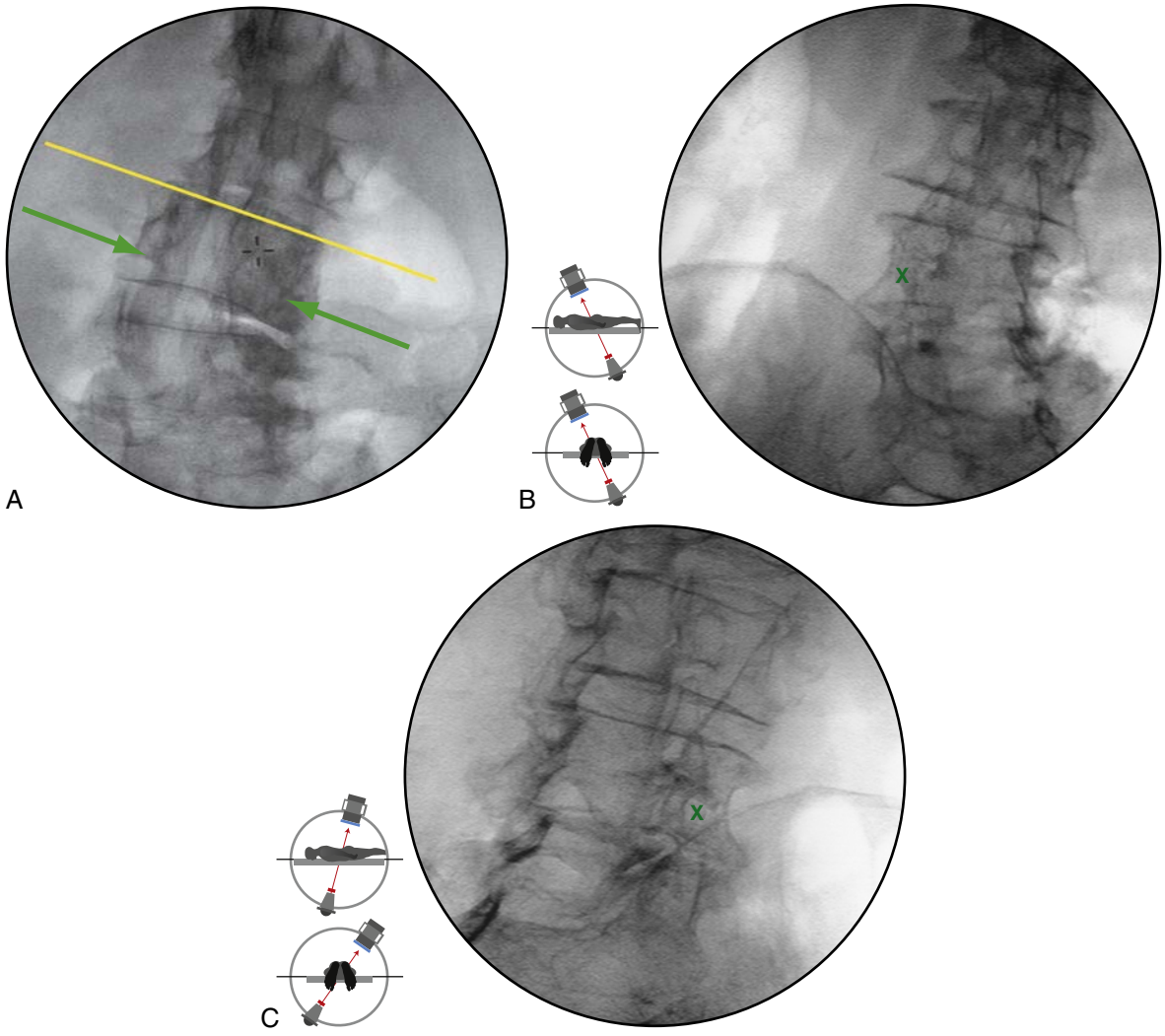

Fig. 3.28. A, An anteroposterior view of lateral scoliosis. The yellow line is at the level of the L4 superior end plate. The green arrows indicate the final target position when performing a procedure with an oblique trajectory view. Note that each side has a different angle, which will necessitate unique oblique and tilt angles for their respective trajectory views. **B** and **C,** Anatomy dictates the setup. Fluoroscopic images of oblique views of a patient with scoliosis, with the green "x" as the trajectory target and the associated tilt and oblique icons. There are less oblique and more cephalad C-arm image intensifier tilt angles in **B** compared with the more oblique and more caudad C-arm image intensifier tilt angles in **C**.

Differentiating Superimposed Superficicial vs. Deep or Bilateral Structures

One of the following techniques can be used to differentiate superimposed superficicial vs. deep or bilateral structures:

1. Oblique the C-arm slightly in one direction. The structure closest to the image intensifier will rotate in the opposite direction (Fig. 3.29). Note this technique can be applied when performing procedures that require differentiating ipsilateral from contralateral (or dorsal from ventral) structures that are superimposed on each other (e.g., cervical medial branch blocks, cervical zygapophysial intraarticular injections via the lateral approach, hip joint injection with lateral approach, and sacroiliac joint injection).
2. The two structures may be superimposed so that the practitioner does not have to differentiate between them if they appear identical as in bilateral structures such as cervical Z-joints visualized in lateral projection.

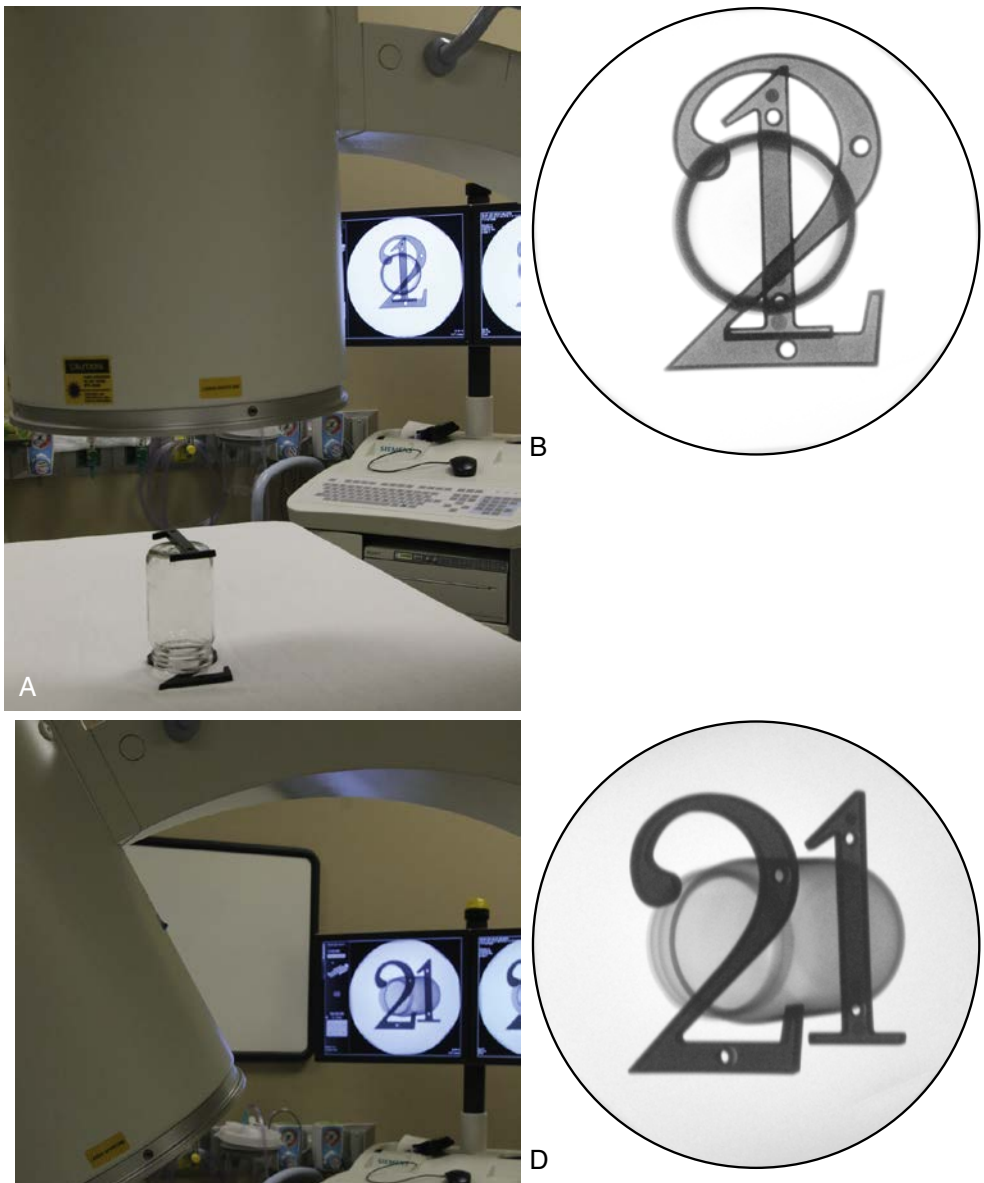

Fig. 3.29. A, Anteroposterior alignment of the C-arm over two objects of equal size (i.e., number 1 on top and number 2 at the bottom) that are superimposed, with a glass jar between them. **B,** Fluoroscopic anteroposterior image corresponding to Fig. 3.29A, with the two objects superimposed. Note the two numbers are equal in size; however, number 1 appears smaller (less magnified) as it is closer to the intensifier. **C,** Left oblique alignment of the C-arm over the two objects. **D,** Fluoroscopic oblique view of two objects corresponding to Fig. 3.29C. Notice how an oblique alignment of the C-arm in one direction (left) results in the object closest to the image intensifier (number 1) moving in the opposite direction (right).

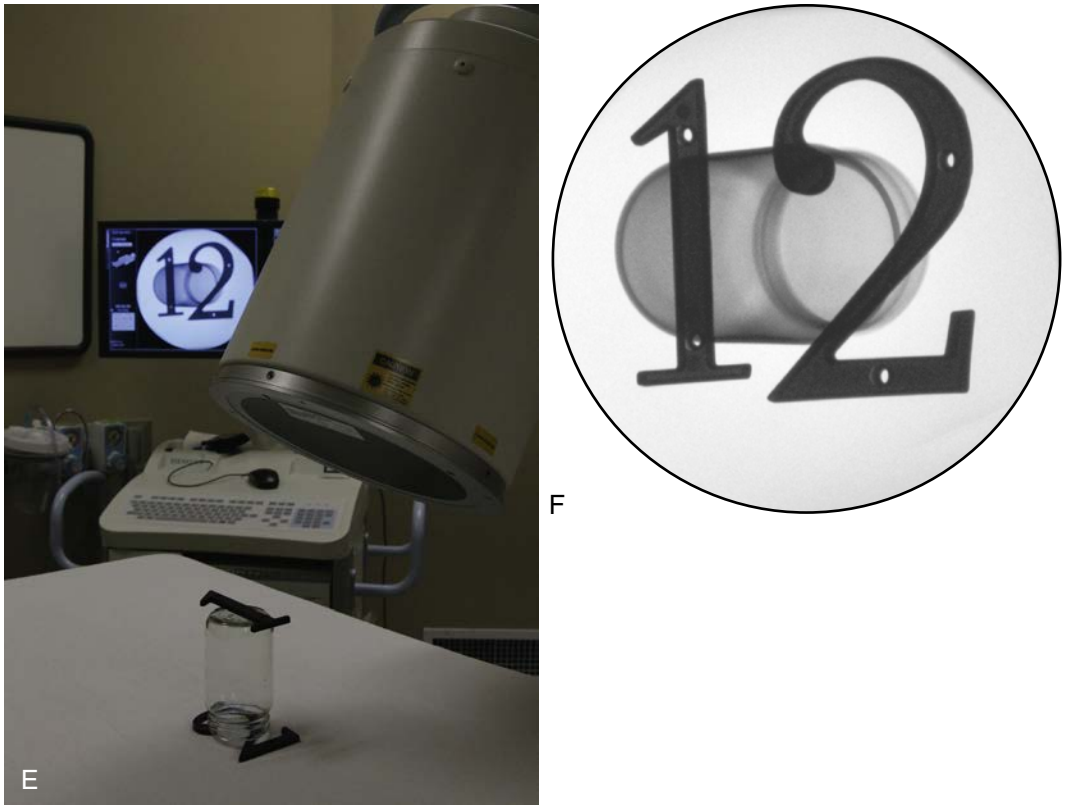

Fig. 3.29 cont'd E, Right oblique alignment of the C-arm over the two objects. **F,** Fluoroscopic oblique view of two objects corresponding to Fig. 3.29E. Note how an oblique alignment of the fluoroscope in one direction (right) results in the object closest to the image intensifier (number 1) moving in the opposite direction (left).

Additional Procedural Pearls

Optimizing the Working Environment

Setup is key!

This includes setting up the work environment in an optimal position (not just the C-arm position). Ideally, the patient should be in front of the interventionalist, the C-arm on the side opposite to the interventionalist, and the fluoroscopic monitor at a location where the interventionalist can see it (without awkwardly turning his or her head around). We also recommend placing the sterile equipment tray on the interventionalist's dominant side. For example, a right-hand-dominant interventionalist should place his or her equipment tray on the right side to prevent crossing over and contaminating the sterile operative field during the procedure (Fig. 3.30).

Bilateral and Multilevel Procedures

Bilateral and/or multilevel procedures may require multiple needles placed simultaneously or sequentially (e.g., medial branch blocks/neurotomy, zygapophysial injections). Therefore, needle placement in the wrong order can interfere with the operative field. For example, if the patient is laying such that the head is to the left, a right-hand-dominant interventionalist will minimize the risk for needle contamination or self-inflicted injury by placing the needles in the following order: from cephalad to caudad and from the right to left side (Figs. 3.31 and 3.32).

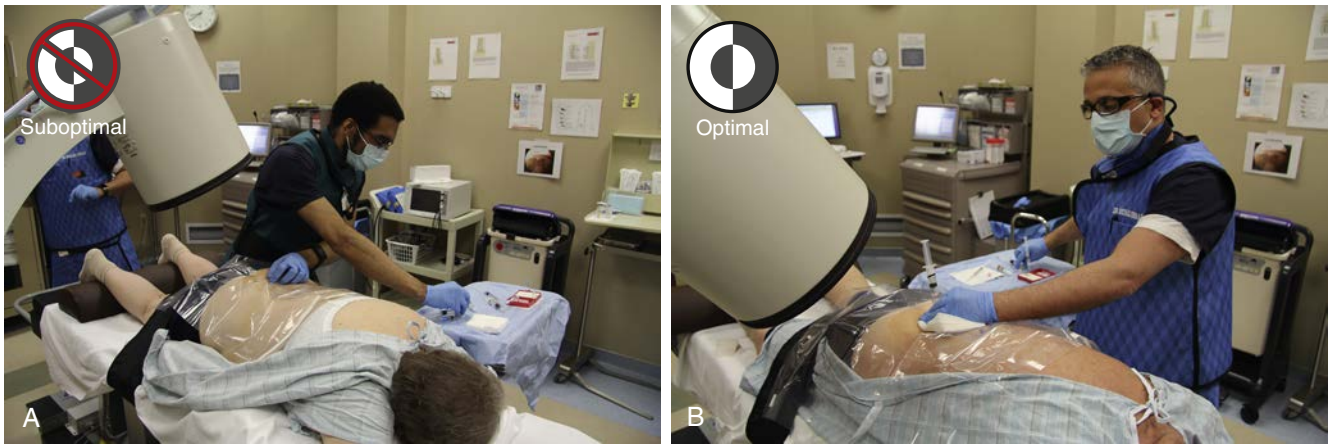

Fig. 3.30. A, An inexperienced right-hand-dominant interventionalist is crossing over to reach for an item on the left (nondominant) side. Doing so may require awkward body repositioning and risk self-injury (e.g., needle stick) or contamination of sterile items. **B,** A more experienced right-hand-dominant interventionalist is reaching to the right side for an item without having to awkwardly reposition his body or cross his arms, and thus keeps the patient and himself safe and the procedure as efficient as possible.

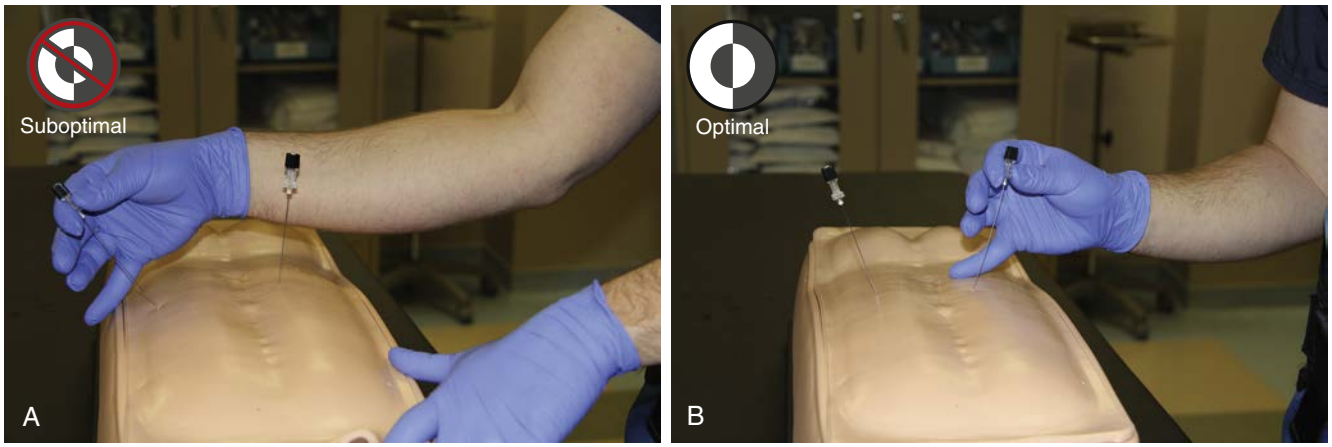

Fig. 3.31. Images of a bilateral procedure performed by a right-hand-dominant interventionalist, with the simulated patient's head toward the bottom of the picture. **A,** The interventionalist placed the first needle on the patient's left side before reaching over to place the second needle on the patient's right side. In this order, the interventionalist must work around the originally placed left needle, which is potentially more challenging and may contaminate the sterile operative field. **B,** The interventionalist placed the first needle on the simulated patient's right side before placing the second needle on the patient's left side. In this order, the interventionalist is less challenged and avoids contaminating the sterile operative field.

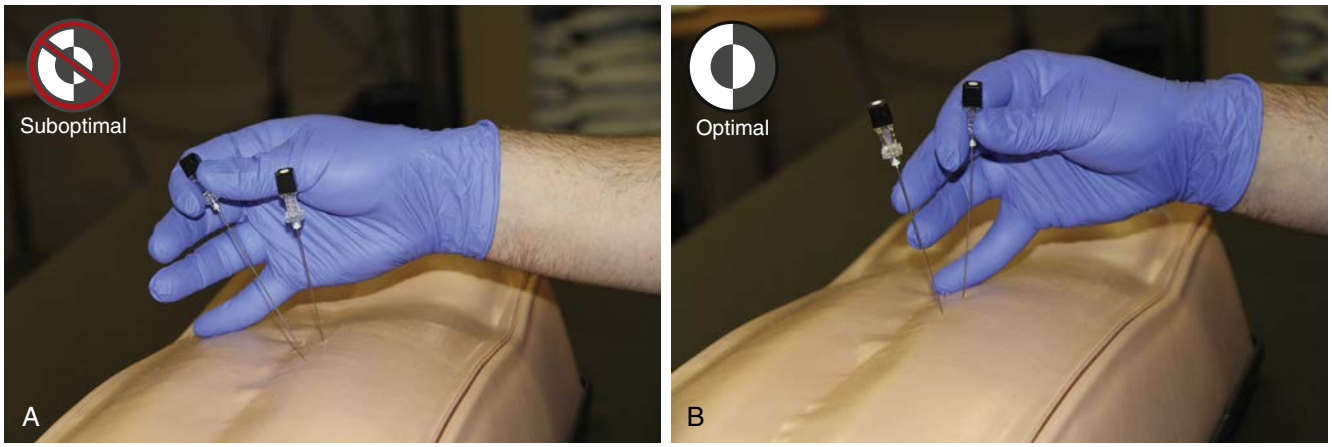

Fig. 3.32. Images of a unilateral multilevel procedure performed by a right-hand-dominant interventionalist, with the simulated patient's head toward the bottom of the picture. **A,** The interventionalist placed the first needle more caudad before reaching cephalad to place the second needle. In this order, the interventionalist is adding the unnecessary potential challenge of working around a placed needle and may contaminate the sterile operative field. **B,** The interventionalist placed the first needle before moving caudally to place the second needle. In this order, the interventionalist will avoid the unnecessary challenge of working around a placed needle and potentially contaminating the sterile operative field. Note that for a bilateral multilevel procedure, we recommend performing this same order on the right side before moving on to the left side.

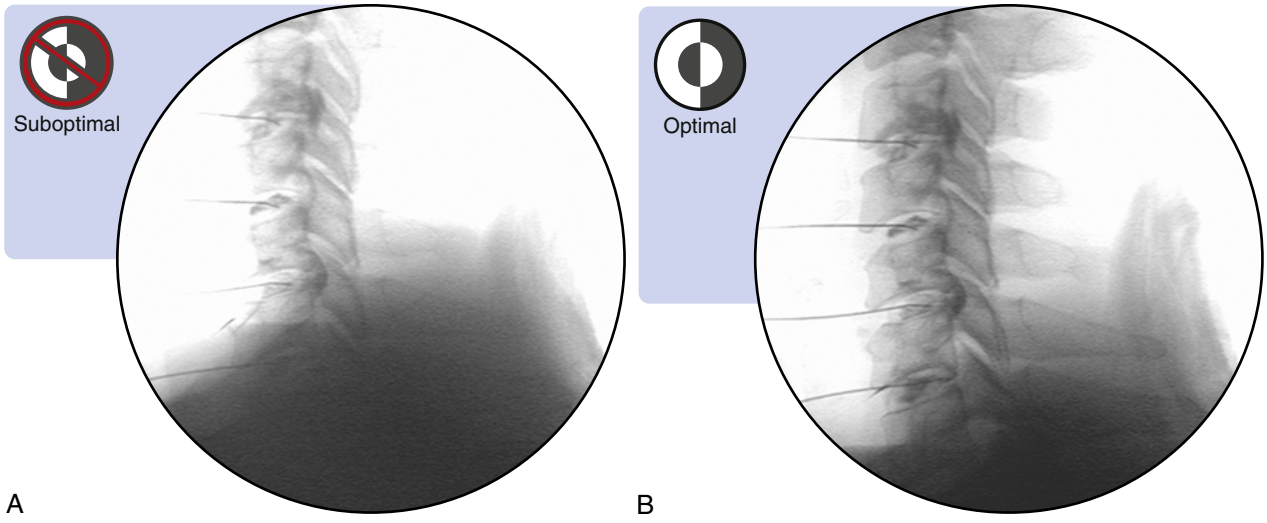

Fig. 3.33. A, Fluoroscopic lateral image during cervical discography. Note the shoulders obstruct the view of the lower cervical segments and inferior-most needle. **B,** The image improves and the lower cervical segments and inferior-most needle can be visualized when the shoulders are relaxed and pulled inferiorly.

Improving Image Quality

Image quality refers to the fidelity or exactness of representation of an anatomic structure on a fluoroscopic image. Image quality can be qualitatively described in terms of characteristics such as detail, contrast, noise, and distortion. Multiple factors determine image quality, such as image production/processing, subject factors, and technique. Technique factors that can be optimized to improve image quality include, but are not limited to, removing obstructing anatomic structures away from the beam, collimation, positioning the patient closer to the image intensifier, minimizing patient motion, dimming room lights or adjusting the contrast setting on the monitor, using manual exposure, and using magnification.

Physically removing obstructing anatomic structures is useful for procedures where the anatomy may overshadow the target, such as the shoulder overshadowing the lower cervical segments during a cervical procedure or the contralateral knee overshadowing the knee of interest (Fig. 3.33).

Collimation can improve image quality and reduce the amount of radiation to which both the patient and operator are exposed (Fig. 3.34).

Manually adjusting the kV output can enhance the contrast of the image. This is useful for areas in which there are multiple tissue densities (e.g., bowel gas), when the C-arm incorrectly tries to automatically adjust. The automatic setting helps to visualize all structures on the screen, but it does not always optimize the structures of interest (Fig. 3.35).

Superimposed Needle Separation

For better visualization of two superimposed needles during a bilateral procedure:

- Wig-wag is useful to distinguish two needles by separating them from each other (Fig. 3.36).
- The right needle can be positioned with the notch cephalad (i.e., bevel up/bend down), and the left needle can be positioned with the notch caudad (i.e., bevel down/bend up) to help with differentiation, assuming that bent needles are used. This allows for needle differentiation when the needles are superimposed on each other in the lateral view (Fig. 3.37).
- Remove the stylet from one of the needles, and it will be more radiolucent (lighter) than the styletted one (Fig. 3.37).
- One needle can be moved at a time to distinguish between the two needles.
- Use two different needle sizes (gauges).

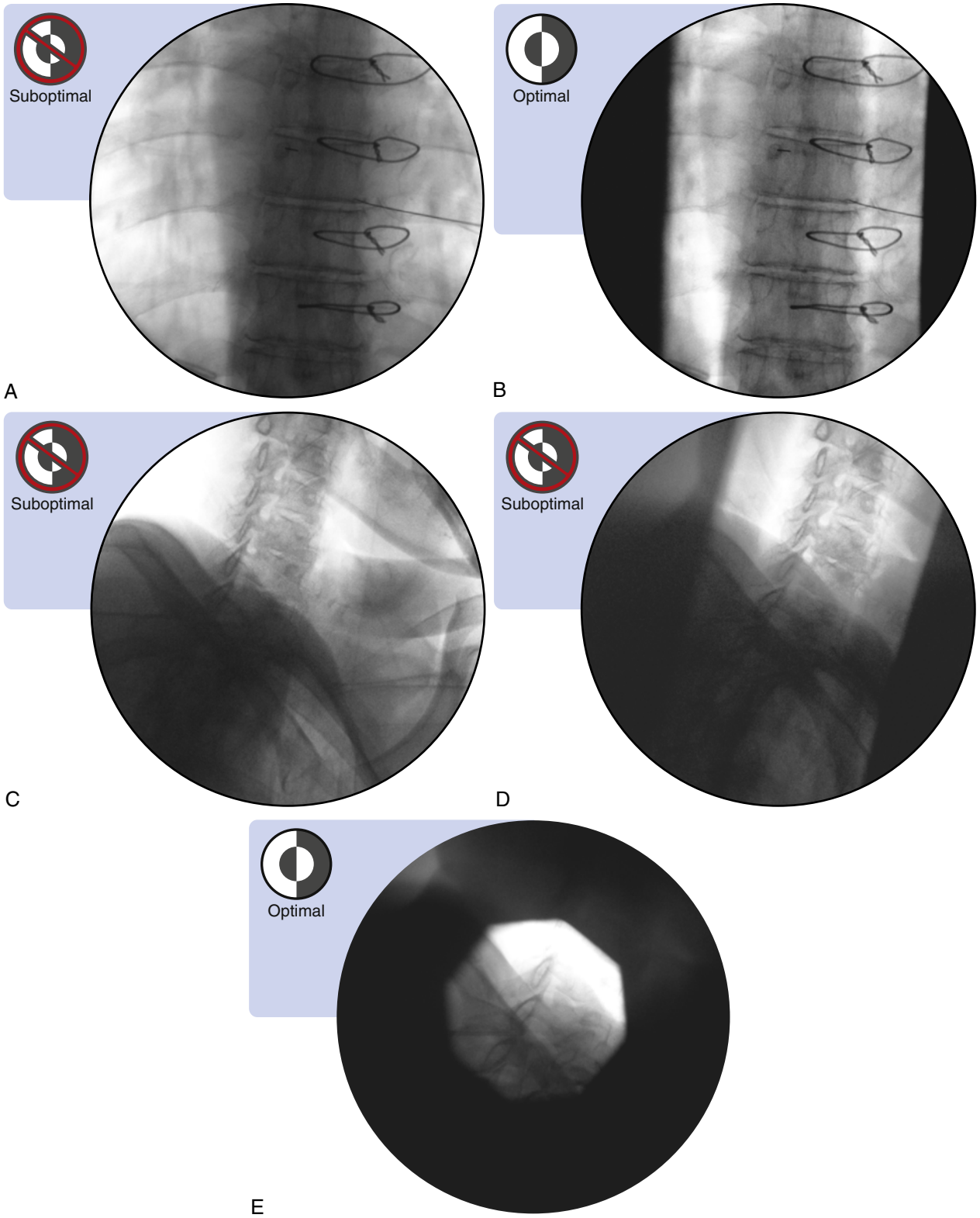

Fig. 3.34. A, Fluoroscopic image without collimation. Note that the thoracic target of interest is poorly visualized because the lung fields and spine have different densities. **B,** Fluoroscopic image with collimation. Note that the target of interest can be better seen. By collimating and narrowing the visualized area, the fluoroscopic's auto-contrast feature improves the image quality. This technique also reduces direct and scattered radiation. **C,** Fluoroscopic C7-T1 interlaminar epidural steroid injection (IL-ESI) contralateral oblique (CLO) image without collimation. The needle and target are poorly visualized. **D,** Fluoroscopic C7-T1 IL-ESI CLO image with linear collimation. Because of the various tissue densities, linear collimation alone does not adequately improve needle and target visualization for this situation. **E,** Fluoroscopic C7-T1 IL-ESI CLO image with iris (circular) collimation demonstrating a significant improvement in needle and target visualization.

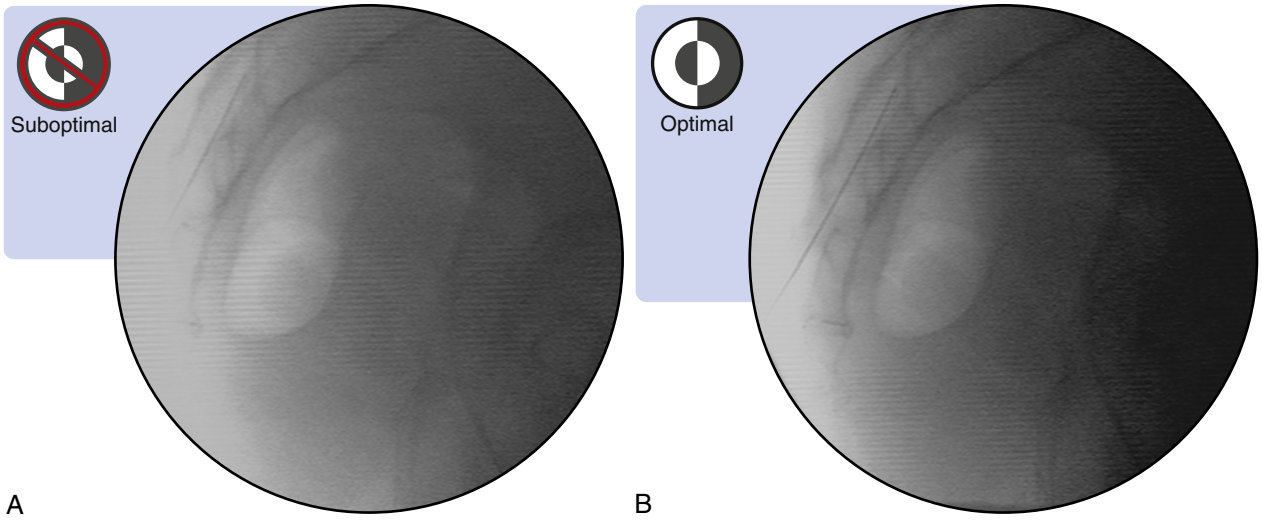

Fig. 3.35. A, High kV output. Note that the anterior hips, but not the sacrum, are visualized. **B,** Low kV output. Note that the sacrum is much better visualized. This image can be improved even more with collimation (not shown; see Fig. 3.34).

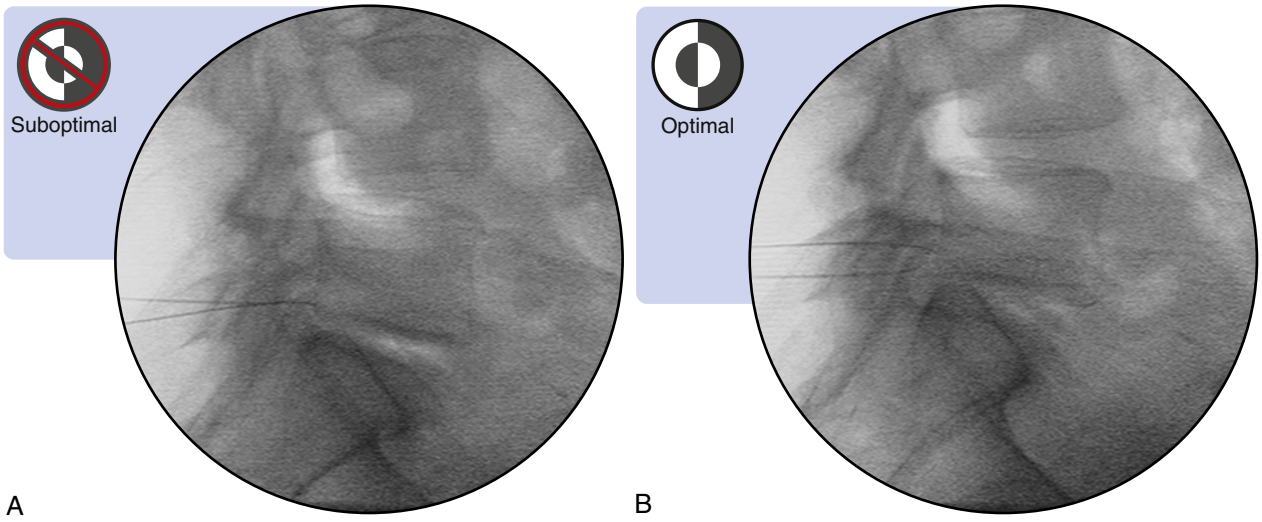

Fig. 3.36. A, Fluoroscopic lateral view, with the two needles superimposed. **B,** Fluoroscopic lateral view, with the two needle tips separated after changing the beam alignment using wig-wag control.

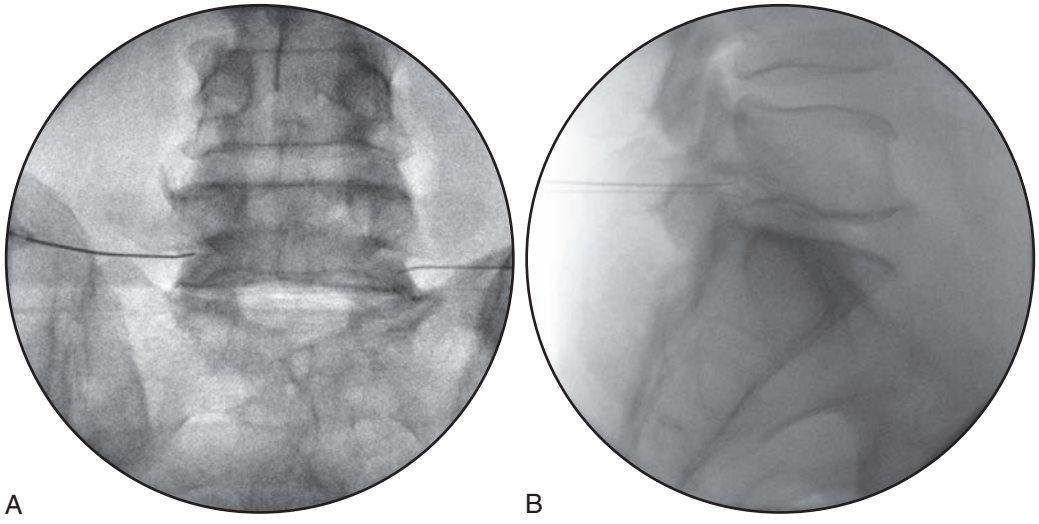

Fig. 3.37. A, Fluoroscopic anteroposterior view, with the right needle placed bend down and stylet removed and the left needle placed bend up with stylet in place. **B,** Fluoroscopic lateral view, with the right unstyletted needle placed bend down and the left styletted needle placed bend up to distinguish the right needles from the left ones.

Needle Displacement to Identify the Needle of Interest

Procedures that require the use of multiple needles (e.g., medial branch blocks) can involve an obstructed view of a needle tip as a result of the presence of adjacent needles. The simple displacement of the adjacent needle hub can enable the visualization of the needle tip of interest (Figs. 3.38 and 3.39).

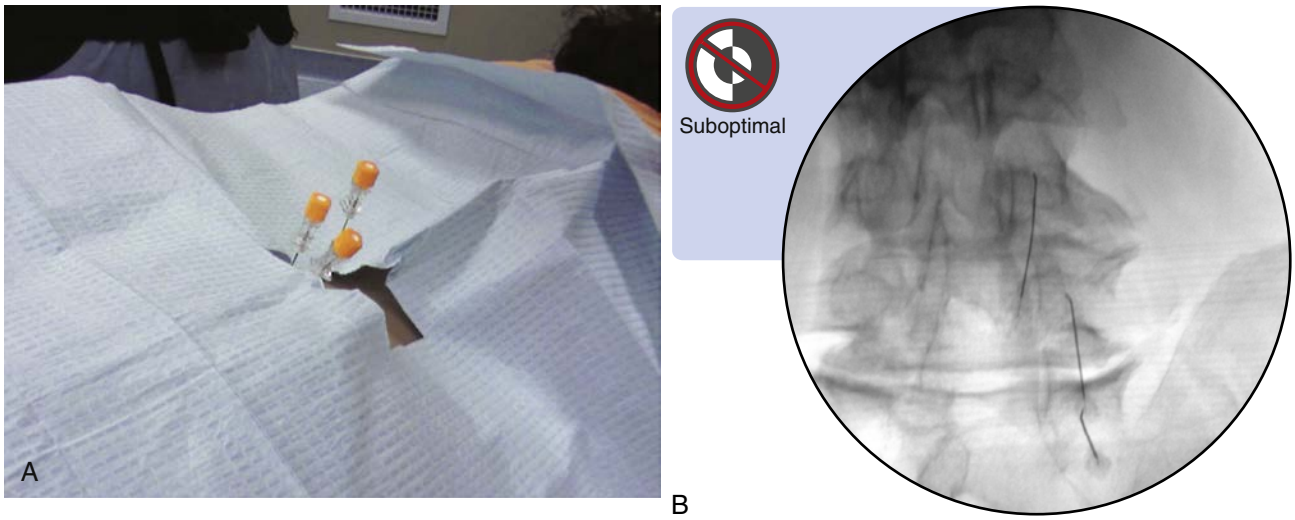

Fig. 3.38. A, Three needles in place for a right L3 and L4 medial branch and L5 dorsal ramus block. **B,** Corresponding fluoroscopic image with the needle tip targeting the L5 dorsal ramus *(bottom)* obstructed by the L4 *(middle)* needle hub. The hub of the needle targeting the L4 medial branch obstructs the L5 needle tip.

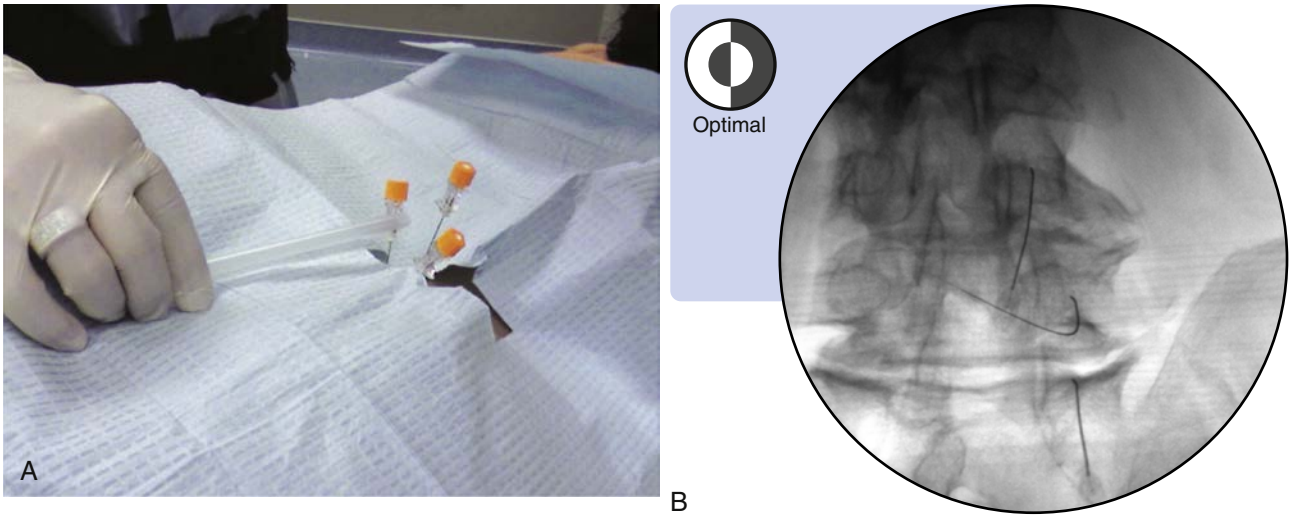

Fig. 3.39. A, A simple way to displace the obstructing needle hub using a radiolucent object. **B,** Corresponding fluoroscopic image with the displacement of the obstructing needle hub. This enables better visualization of the needle tip of interest (compared with Fig. 3.38B).

"Live" Contrast Flow and Digital Subtraction Imaging

Stepping and holding on to the fluoro side of the foot pedal (see Fig. 3.3C) while injecting the contrast allows the interventionalist to visualize the flow of contrast in real time. One specific advantage with this is the ability to visualize the vascular uptake, which appears serpiginous for the duration of the live contrast flow and disappears quickly after contrast injection is stopped. A moment later, the interventionalist can also use the "snapshot" setting of the foot pedal to retake a static image to confirm that the serpiginous vascular flow has dissipated. We demonstrate static and dynamic examples of contrast patterns throughout this atlas.

Digital subtraction imaging (DSI) is a technology that literally digitally subtracts out the current image or "mask." By subtracting out the mask, the interventionalist can visualize new versus previous contrast flow in real time, without overlapping radiopaque structures such as bones or fusion hardware. Its utility is in enabling the visualization of contrast flow in the epidural space, along the nerve root or to verify the absence of vascular uptake without radiopaque structures or previously placed contrast obscuring the view.

Fig. 3.40 and Video 3.1 demonstrate the use of DSI to observe new contrast on top of a previous suboptimal pattern, which can be subtracted away. Please see other chapters for further examples of DSI use.

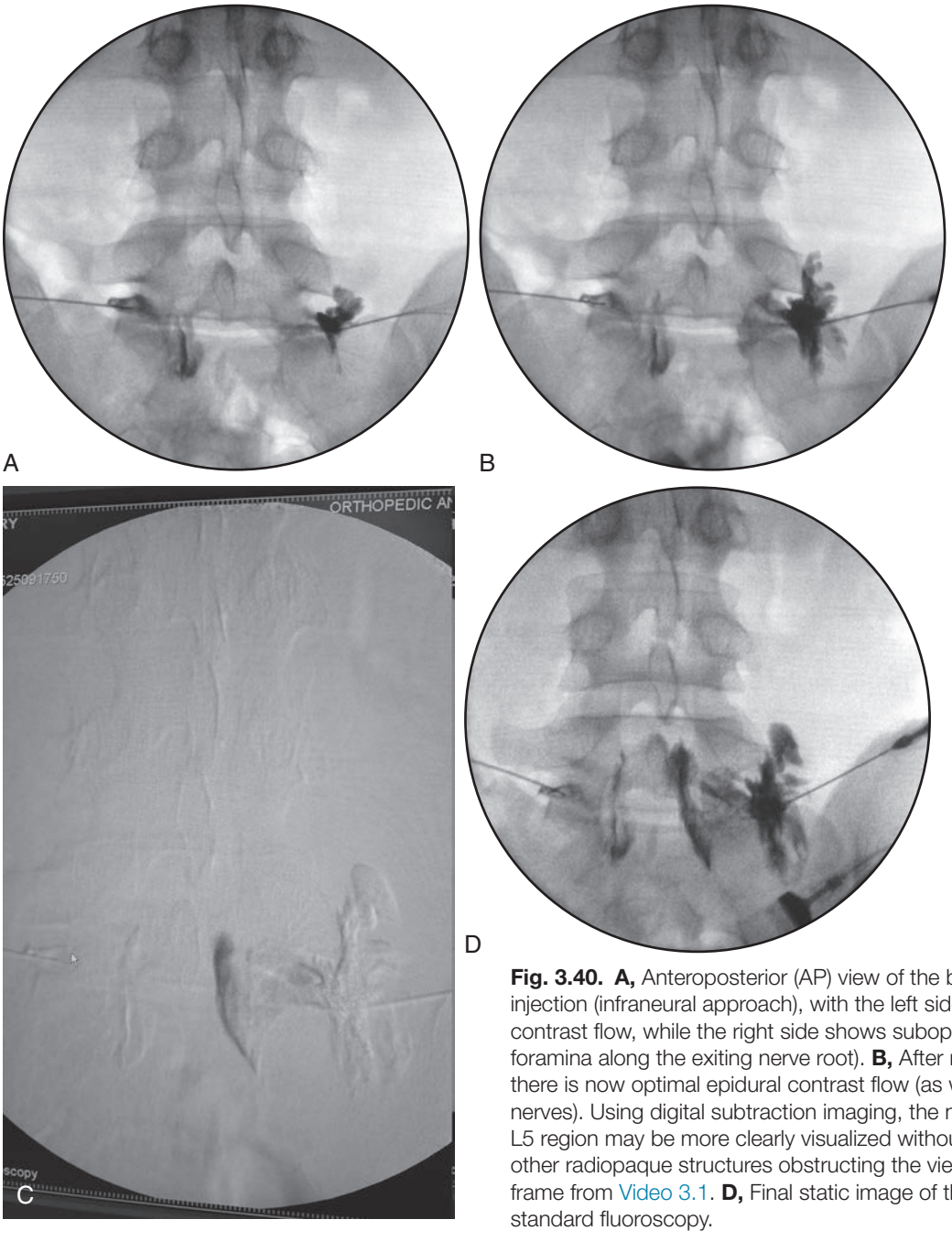

Fig. 3.40. A, Anteroposterior (AP) view of the bilateral L5 transforaminal injection (infraneural approach), with the left side showing optimal epidural contrast flow, while the right side shows suboptimal contrast flow (extraforamina along the exiting nerve root). **B,** After right-sided needle adjustment, there is now optimal epidural contrast flow (as well as the L5 and S1 spinal nerves). Using digital subtraction imaging, the newer contrast flow of the right L5 region may be more clearly visualized without the previous contrast or other radiopaque structures obstructing the view (see Video 3.1). **C,** Static frame from Video 3.1. **D,** Final static image of the contrast visualized with standard fluoroscopy.

Video Using digital subtraction imaging, the most updated right L5 contrast flow is visualized clearer. The flow pattern is no longer obscured by the previously injected contrast or other radiopaque structures. This corresponds to Fig. 3.40.

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CHAPTER 4

Ultrasound Techniques and Procedural Pearls

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Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

INTRODUCTION

This chapter provides a basic introduction to ultrasound and its use in interventional procedures. We will discuss several ways to improve image quality and optimize the features of ultrasound that make it an invaluable tool. Sonographic anatomy of the relevant spinal structures and landmarks will be reviewed. In this atlas, we will discuss "hybrid" techniques in which ultrasound and fluoroscopy are combined to enhance safety and precision, minimize discomfort, and reduce radiation exposure for interventional procedures.

ULTRASOUND EQUIPMENT

Base Unit (Fig. 4.1)

- Comprises the screen on which the ultrasound image is displayed, as well as the keyboard and control dials or buttons.
- Some instruments offer touch-screen capabilities and a track pad on a keyboard.

Fig. 4.1. Example of a standard ultrasound base unit.

Transducers

- Transducer selection will vary depending on the type of injection and depth of the target structure. Selecting the appropriate transducer for each injection will result in improved image quality and needle guidance.

Linear (Fig. 4.2)

- Frequency: middle to high range (6–18 MHz).
- Optimal use: neck, shoulders, hips in thin/athletic patients, and shallow to medium depth structures.

Fig. 4.2. Example of a linear transducer. (©FUJIFILM SonoSite, Inc. Bothell, Washington.)

Curvilinear (Fig. 4.3)

- Frequency: low to middle range (2–6 MHz).
- Optimal use: lumbar spine, hips in medium/obese patients, deep structures, when a broad field of view is desired, and for steep (>45 degrees) needle approaches.

Fig. 4.3. Example of a curvilinear transducer. (©FUJIFILM SonoSite, Inc. Bothell, Washington.)

Hockey Stick (Fig. 4.4)

- Frequency: high range (10–18 MHz).
- Optimal use: small superficial joints, tendons, and nerves.

Fig. 4.4. Example of a hockey stick transducer. (©FUJIFILM SonoSite, Inc. Bothell, Washington.)

KNOBOLOGY

- Ultrasound knobs, dials, and buttons.

Image/Video Loop Capture

- Static images are obtained and saved for review and or documentation.
- Video loops are used to document dynamic pathologies (e.g., snapping hip) and or procedural details (e.g., aspiration of a cyst or injectate distribution).

Freeze

- Images can be "frozen" for immediate evaluation, during which on-screen structures can be labeled, measured, and if using dual screen mode, compared to contralateral structures.
- If the interventionalist/sonographer sees something interesting and would like to see it again, freezing the image and rolling the trackball or touchpad to the left typically rewinds through the last 5 to 10 seconds of scanning.

Depth/ Frequency (Fig. 4.5A, B)

- Lower frequency transducers and settings will allow the ultrasound beam to penetrate further, thus allowing visualization of deeper structures though usually at the cost of image quality.
- Higher frequency settings and transducers will allow one to see more superficial structures in greater detail with generally excellent image quality usually at the cost of visualizing deeper structures.
- The depth (in centimeters or millimeters) of a particular structure can be estimated on the basis of hash marks on the side of the screen, or precisely measured using the ultrasound unit caliper feature.

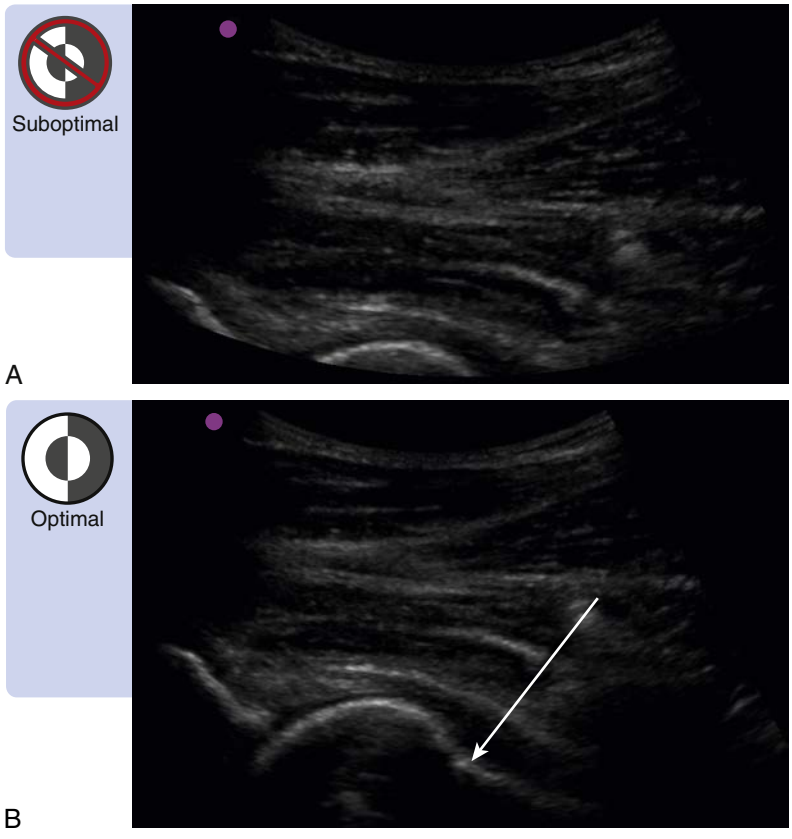


Fig. 4.5. Hip ultrasound: **A,** Insufficient depth selection. **B,** More appropriate depth selection. Note how the femoral head with femoral head/neck junction (arrow) is better visualized with an increased depth.

Caliper

- The caliper feature is used to measure depth, length, and area and is useful for estimating needle length and angle of approach for procedures or diagnosis of nerve or tendon enlargement and response to treatment.

Gain (Fig. 4.6A, B)

- Adjusts overall brightness of the screen, typically using a dial.
- Some units have slide controls (also known as time-gain compensation [TGC]), which adjust brightness at different depths.

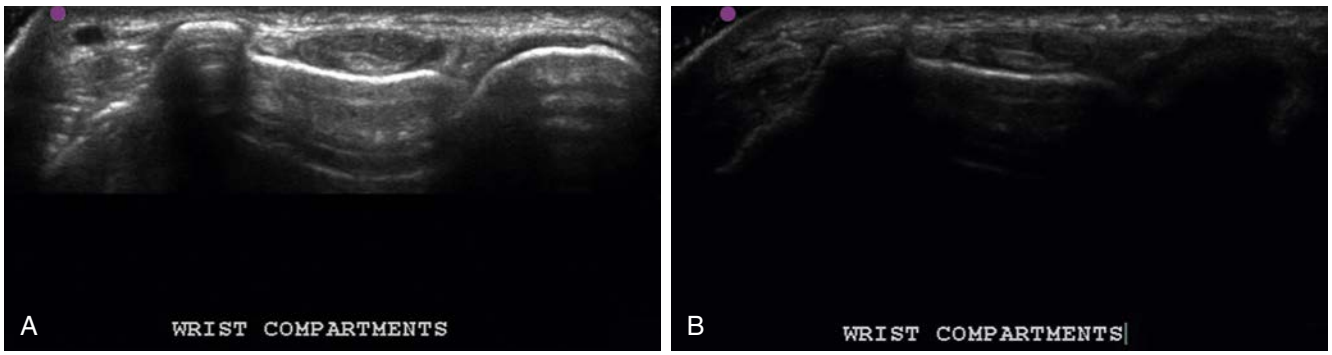


Fig. 4.6. A, Higher gain setting selected. Note the bright cortical surface. **B,** Lower gain. Cortical surfaces are darker, as is the surrounding tissue.

Color Doppler/Power Doppler (Fig. 4.7A, B)

- Highlights vascular structures and vascular flow.
- Red color indicates flow toward the transducer and blue away from the transducer.
- Lighter shades of red or blue indicate higher velocity flow.
- Power Doppler indicates flow in any direction and may be more sensitive than color Doppler depending on the ultrasound unit.
  - Can be used to assess neovascularization and inflammation.
  - Can be used to assess and/or confirm injectate flow, especially for deeper structures.
- Dual split screen capability facilitates the comparison of vascular and musculoskeletal structures.

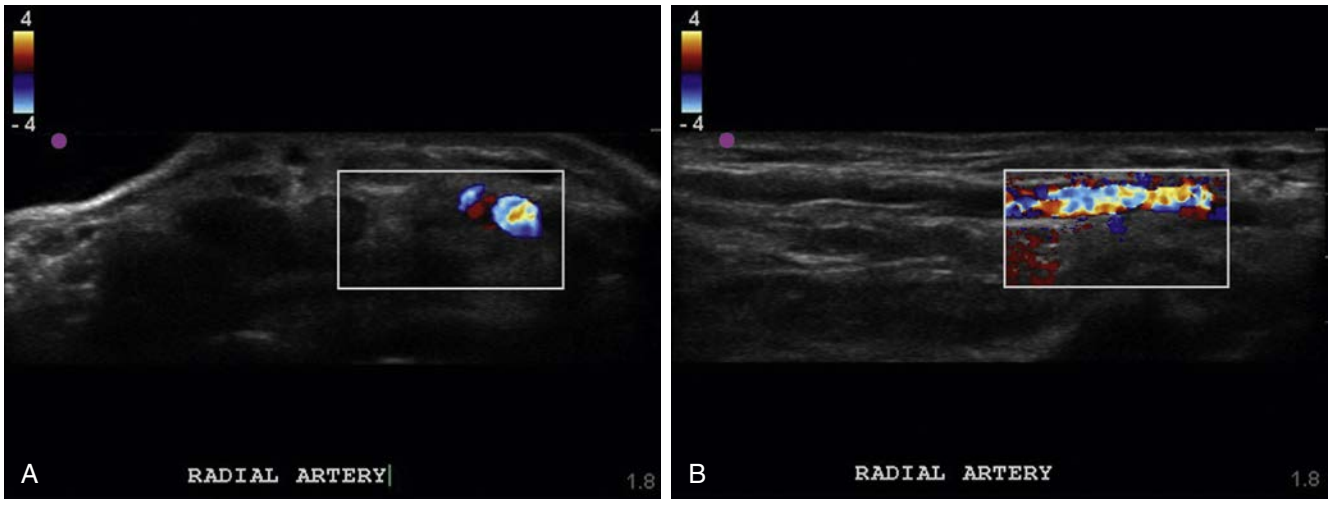


Fig. 4.7. A, Example of color Doppler flow of a vessel in short axis, depicted as blue circle, indicating cross-section of the vessel flowing away from the transducer. **B,** Example of color Doppler flow of the radial artery in long axis.

Zoom (Fig. 4.8A, B)

- Magnifies an area of interest for improved resolution and visualization.

Focal Zones (Fig. 4.8C, D)

- Focal zones optimize image quality at a particular depth. The size and location of the focal zone can be adjusted on some units with a knob or dial, while others have it set to the middle of the screen. To make appropriate adjustments, it is important to know the type of machine used. For machines with the focal zone set to the middle of the screen, it is important to adjust the depth such that the structure of interest is in the middle of the screen.

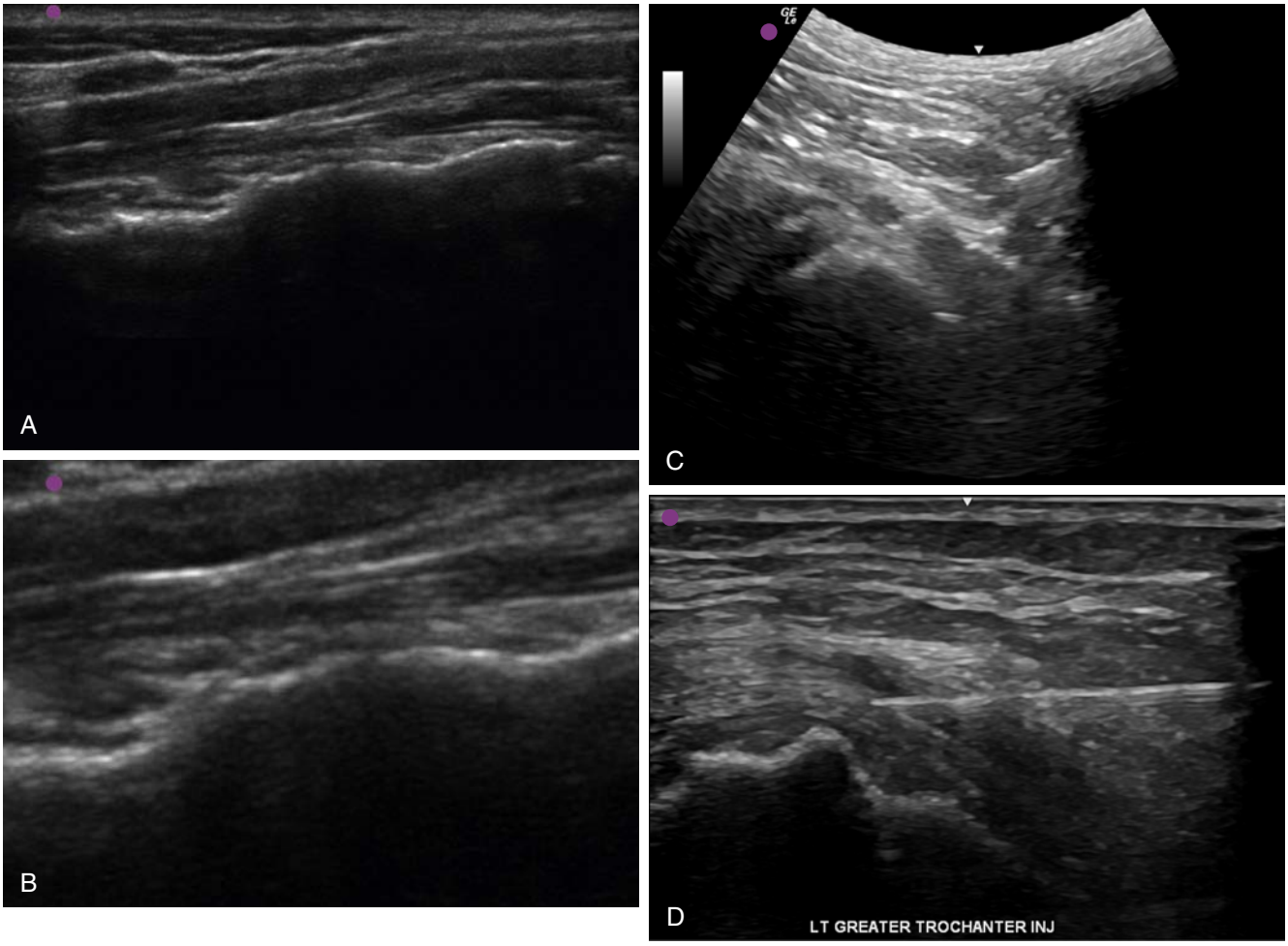


Fig. 4.8. A, Standard image without zoom. **B,** Zoomed in image on an area of interest. **C,** Standard and **D,** optimized use of focal zones.

Needle Enhancement/M-Line Needle Enhancement (Fig. 4.9A)

- The needle enhancement software incorporates ultrasound beam steering and other features to improve needle visualization. This can be a useful feature when injecting at steep angles and into deep structures.

M-line (Fig. 4.9B, C)

- To facilitate out-of-plane injections, some machines have a hash mark under the middle part of the transducer and a corresponding line, the "M-line" (center line), which can be turned on and off on the screen. Structures located under the hash mark will be seen in the middle of the ultrasound screen and marked by the "M-line."

Note: The most important part of being able to see a needle well depends on whether the interventionalist properly aligns the needle with the transducer and ultrasound beam.

Extended Field of View (Fig. 4.9D)

- This is a method in which the user can visualize an anatomic structure and sweep along it to obtain images that are reconstructed to form a panoramic view of the structure.
- It can be difficult to create a smooth panoramic image, as any nonlinear motion of the transducer will create a "choppy" appearance.

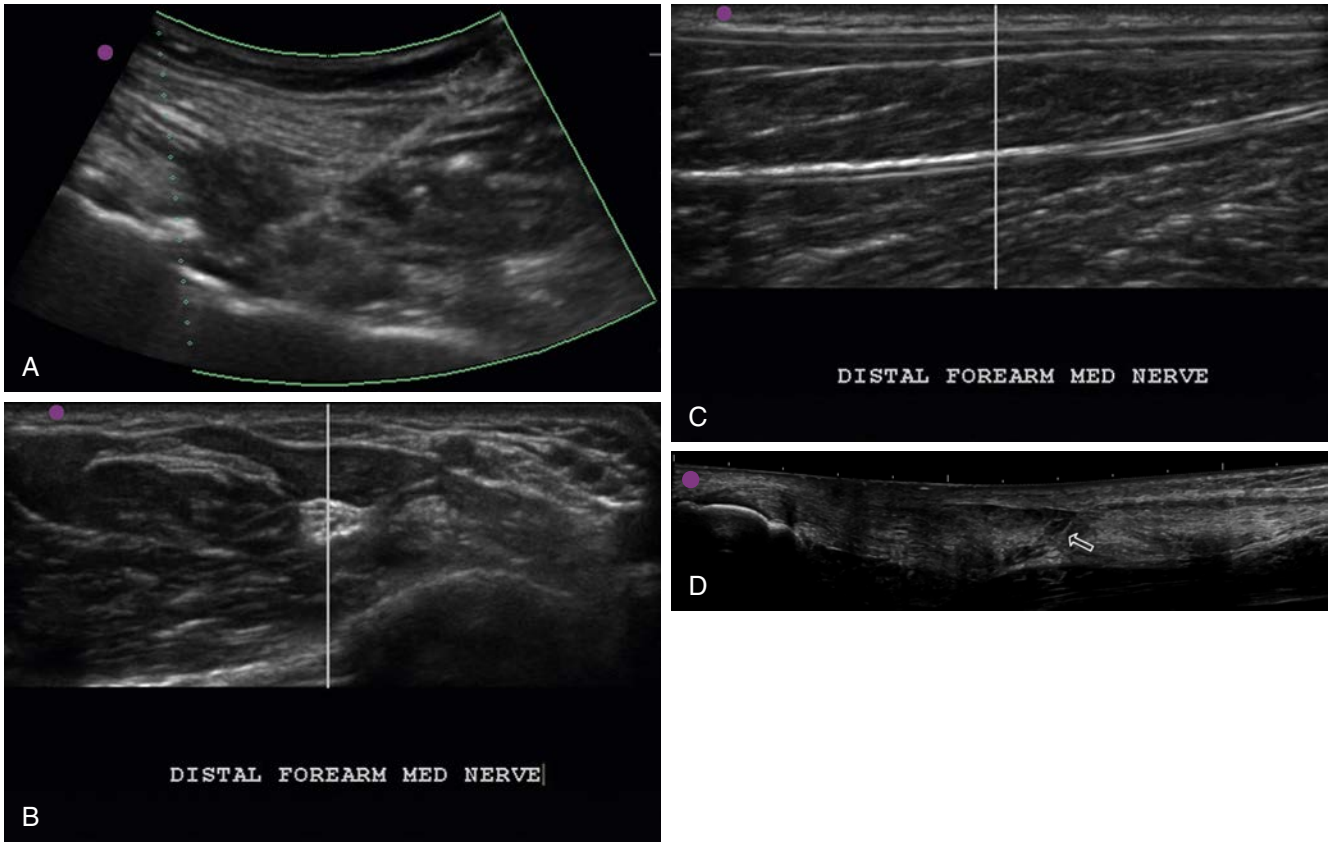


Fig. 4.9. A, Example of needle guidance during a hip injection using a curvilinear probe. The needle is coming from the right, nearly perpendicular to the ultrasound beam depicted by the dotted line and steered using the needle enhancement software. Despite a suboptimal image, needle visualization is improved. **B,** M-line (center line) is used here to center the structure of interest (nerve) in the short axis. **C,** M-line (center line) is used here to indicate the midpoint of the transducer footprint in the long axis. **D,** Example of using "Extended Field of View" to visualize an Achilles tendon rupture in the long axis (arrow).

ULTRASOUND ERGONOMICS

Optimal Setup (Fig. 4.10)

- The patient and ultrasound unit are positioned close to each other, ideally with the patient positioned between the interventionalist and the monitor.
- A straight-line or narrow angle orientation between the interventionalist, ultrasound transducer, and screen is best. This helps minimize extraneous operator movement, as even the most subtle movement can cause misalignment of the transducer, needle, and target.
- An assistant can be helpful in capturing images, adjusting knobs, and handling supplies, allowing the interventionalist to concentrate on the procedure and maintain sterility.
- The unit can also be positioned next to the patient on the same side as the interventionalist for better access to controls and lessen the need for an assistant.
- See Chapter 5 for more details on patient safety, positioning, and procedure room setup.

Fig. 4.10. A and **B,** Example of an optimal ergonomic setup for an ultrasound-guided procedure. Note the height of the ultrasound screen across from the physician, at or above the eye level, and the direct line of sight with the needle trajectory and the screen.

Transducer Grip

Optimal

- Option 1: A firm grasp on the transducer, wrapping fingers and thumb at the base of the transducer and leaning the base of the hand and transducer on the patient (Fig. 4.11).
- Option 2: The thumb and index and middle fingers hold the transducer. These fingers form a tripod, an inherently stable structure. The remaining ring and little fingers and transducer itself form a second tripod, which can be stabilized on just about any contour of the human body (Fig. 4.12).

Fig. 4.11. Example of an optimal transducer grip, with relaxed but firm grasp on the base of transducer, with hypothenar eminence resting on the patient's skin and C grip formed by the index finger and thumb. This grip maximizes control and minimizes hand strain or fatigue.

Fig. 4.12. Alternate example of an optimal transducer grip.

Suboptimal (Fig. 4.13)

- Lack of contact between the base of the hand (or little and ring fingers) and the patient, causing ultrasound transducer to slide around and result in a moving target on the ultrasound screen.
- Excessively firm grip on the transducer is likely to cause fatigue, making subtle movements and adjustments of the transducer more difficult.

Fig. 4.13. Example of a suboptimal transducer grip. Note the lack of contact with patient and the loose and high grip on transducer.

ULTRASOUND TRANSDUCER MOVEMENTS

Tilt (Toggle) (Fig. 4.14)

- Tips the transducer toward one of its long sides.

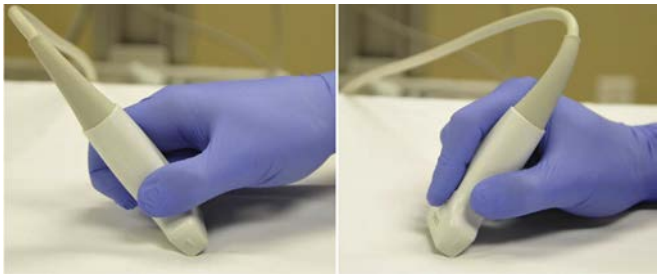


Fig. 4.14. Depiction of transducer tilt.

Translation (Fig. 4.15)

- Slides the transducer horizontally along the skin surface

Fig. 4.15. Depiction of transducer translation.

Rotation (Fig. 4.16)

- Rotates the transducer around its central axis.

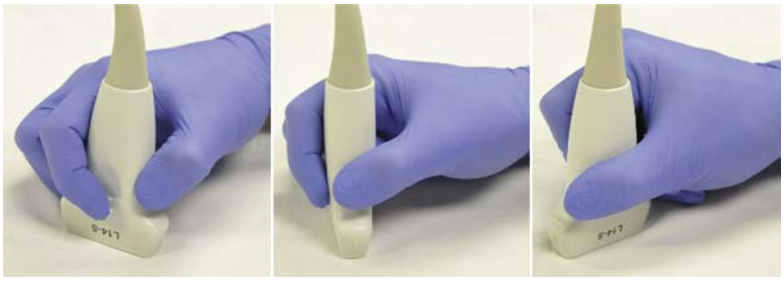


Fig. 4.16. Depiction of transducer rotation.

Heel-Toe/Rocking (Fig. 4.17)

- Raises or lowers one end of the transducer.
- This technique may be particularly helpful for steep angle injections to help keep the sound beam as perpendicular to the needle as possible, e.g., hip intraarticular injections.

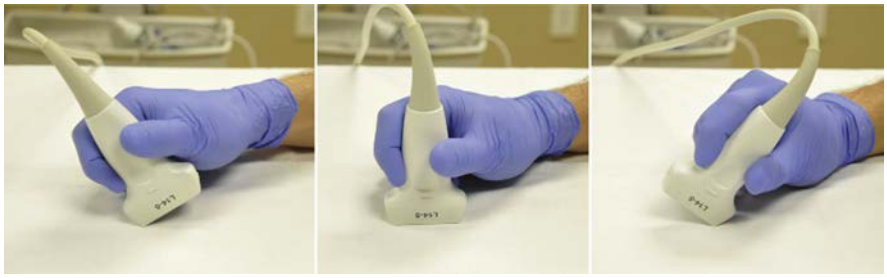


Fig. 4.17. Depiction of heel-toeing the transducer probe.

Adjustment of Transducer Pressure (Fig. 4.18A, B)

- Changing transducer pressure can drastically change the image.
- Varying transducer pressure can be used to assess compressibility of structures.
- Varying transducer pressure can be used to alter the path of a needle.
- Alternately increasing and decreasing the transducer pressure causes compressible fluid-filled structures such as veins, arteries, and bursae to contract and expand and be more easily recognized.
- Excessive transducer pressure compresses underlying tissues, potentially causing pain or leading to the underestimation of the depth of a target structure.

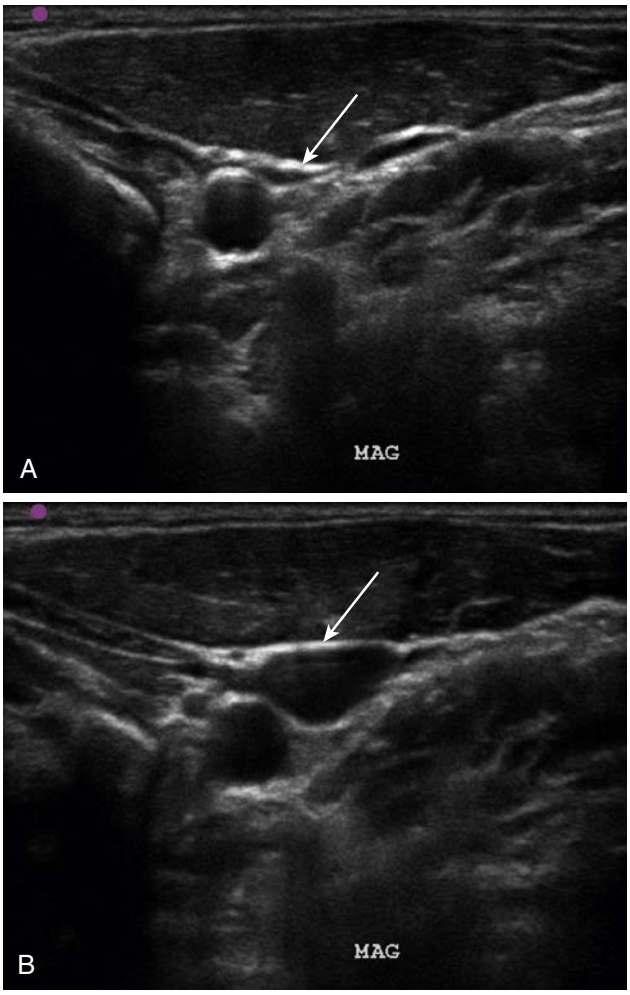


Fig. 4.18. A, Increased probe pressure. Note the compression of the larger vessel in the center of screen (arrow), flattening its appearance (suggestive of a vein) and normal caliber of the other vessel (suggestive of an artery). **B,** Example of lighter probe pressure. Note the less compressed appearance of the larger vessel (arrow) in the center of the screen.

Sonopalpation (Fig. 4.19)

- Sonopalpation can be a very useful technique for confirming a musculoskeletal pain source. The transducer is used to apply pressure over a visualized structure that is suspected to be a pain generator. Concordant tenderness with sonopalpation may help localize the pain source but has to be interpreted judiciously by evaluating adjacent and possible contralateral structures. False positives can arise with excessive transducer pressure, sonopalpating too broad of a region, or in patients with generalized hypersensitivity.

Fig. 4.19. A, An image of the greater trochanter, gluteal tendons, and surrounding bursae without sonographic palpation. **B,** An image of the same with sonographic palpation. Note the compressed soft tissue structures superficial to the gluteal tendons. Patient described concordant tenderness with this maneuver.

DEFINITIONS OF VIEWS/APPROACHES

Axes

Refers to the orientation of the ultrasound transducer relative to the structure of interest. Short and long axis views are obtained by rotating the transducer 90 degrees relative to each other.

Long Axis (Fig. 4.20A)

- Long axis is positioning the transducer parallel to the structure of interest.
- Long axis view, using the long finger flexors as an example, shows tendons extending across the screen.

Short Axis (Fig. 4.20B)

- Short axis is positioning the transducer perpendicular to the structure of interest.
- Short axis view, using the finger flexors as an example. Note the circular appearance of the tendons seen in cross-sectional view and their compact fibrillar structure.

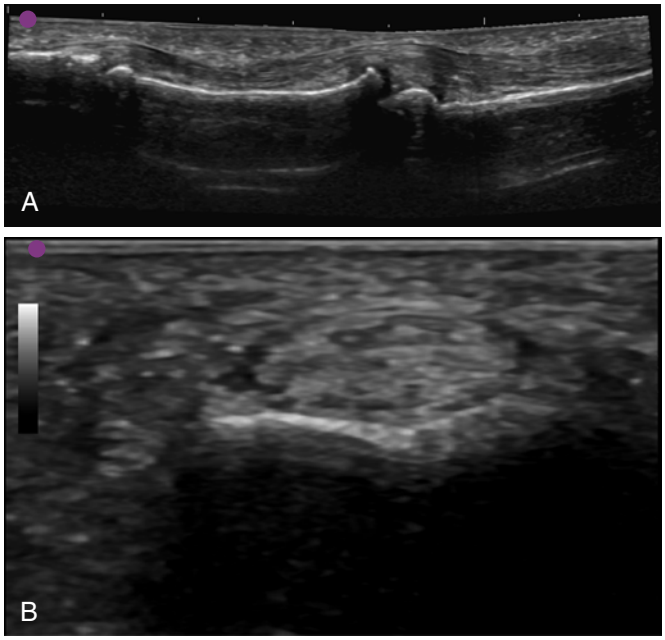


Fig. 4.20. Finger flexor tendons. **A,** Long axis view. **B,** Short axis view.

PLANES

"Plane" refers to the orientation of the *needle* relative to the ultrasound transducer.

In-Plane (Fig. 4.21A, B)

In-plane is defined as an approach with the needle parallel to the ultrasound transducer.
Optimally, the entirety of the needle, especially the tip, will be visualized in an in-plane approach. Visualizing the tip of the needle is the most important part if complete needle visualization is difficult.

In-Plane Needle Optimization

- Needle is inserted under the short edge of the transducer and passed under its long axis.
- Needle has to be within the same plane as the ultrasound beam, which is 0.5 to 1.0 mm wide, and emitted out from under the middle of the transducer.
- Needle is advanced at a relatively shallow angle (10° –45°) to optimize the visualization.
- Needle and its tip are seen as a continuous white line as the needle is being advanced to its target.
- In-plane injection technique is the most precise and preferred method and is always used for deeper structures unless an out-of-plane technique is clearly indicated.
- Needle enhancement and steer mode improve needle visualization by directing ultrasound waves at a higher angle of incidence to the needle and increasing reflectivity back to the transducer.
- Driving the needle with the bevel up toward the transducer helps with visualization of the needle tip.

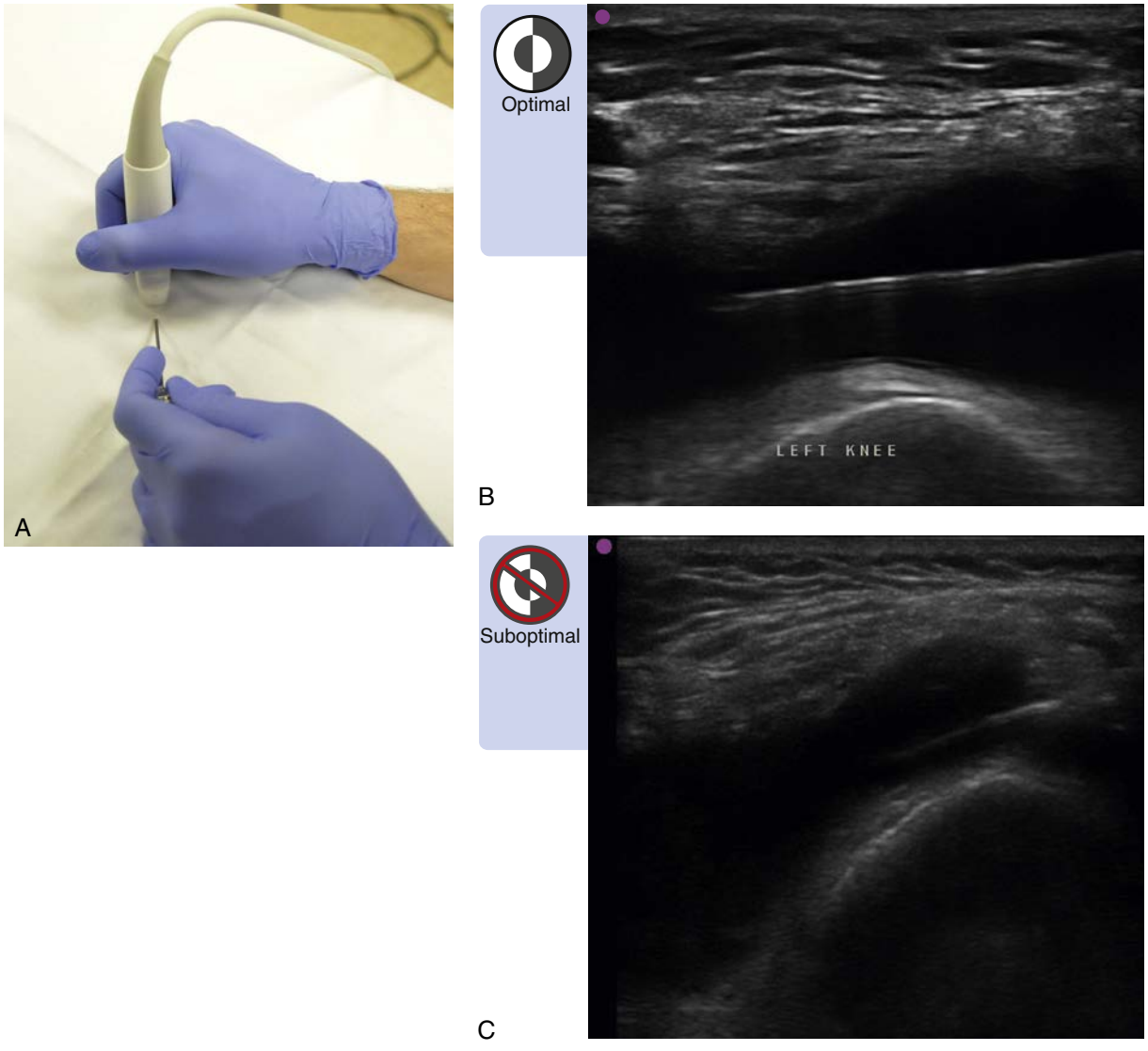


Fig. 4.21. A, Optimal approach for in-plane injection. Note the needle entry at the midpoint of the transducer, parallel to the probe's orientation. **B,** Screenshot of an optimal in-plane knee injection. Note the visualization of the needle in its entirety. **C,** Screenshot of a suboptimal in-plane injection. Note the partial visualization of the needle due to the steeper approach.

Out-of-Plane (Fig. 4.22A, B)

- Out-of-plane is defined as the needle being perpendicular to the ultrasound transducer.
- Needle is inserted under the long edge of the transducer, usually in the middle.
- Needle is seen in cross-section and appears as a white dot or small oval.
- Best for superficial narrow structures such as the acromioclavicular joint.
- Needle can be "walked-down" until it reaches the desired depth, which is described in detail later in the chapter.
- M-line or center line (see above description) indicates the midline of the transducer.
- Rotating the needle tip can help with visualization of the bevel when it is directly under the beam.

In-plane and **out-of-plane** refer to the needle orientation relative to the ultrasound beam/transducer. **Long axis** and **short axis** refer to the orientation of an anatomic structure relative to the ultrasound beam/transducer.

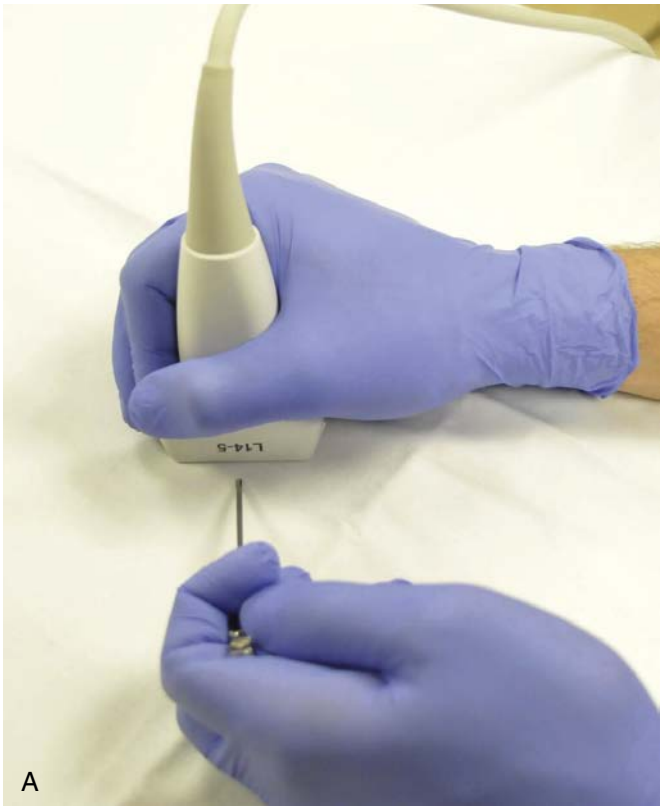


Fig. 4.22. A, Optimal approach for an out-of-plane injection. **B,** Screenshot of an out-of-plane injection. Note the white dot in the left center of the screen indicating the needle tip (arrow) is located within the suprapatellar recess of the knee joint (arrow).

ADDITIONAL TIPS AND TRICKS

Gel Buildup/Standoff (Fig. 4.23A, B)

- Used to facilitate in-plane injections when adjacent structures block or prevent safe needle entry.
- Also helpful for injecting very superficial structures with an in-plane technique.
- A mound of sterile ultrasound gel is placed over the area of interest.
- One end of the ultrasound transducer is placed on the patient and the other end is elevated with the mound of sterile ultrasound gel underneath.
- The needle is passed through the gel on the way to the target.
- The standoff technique allows the needle to be directed at a high angle relative to the patient, thus avoiding obstacles or vulnerable structures, but at the same time be visualized well at a low angle relative to the transducer.

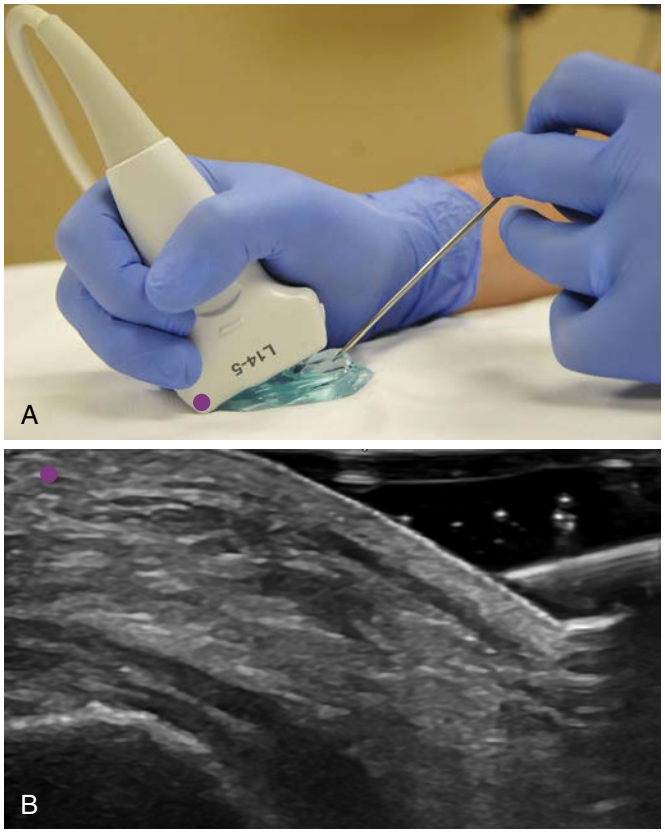


Fig. 4.23. A, Example of needle entry using the gel buildup/standoff technique. Note how the needle passes under the edge of the transducer within the gel, prior to entering the skin. **B,** Ultrasound image of the above.

Triangulating for Depth

- Helps minimize the number of needle passes to the target, especially for out-of-plane injections.
- The interventionalist estimates or measures the distance to the target (see Depth/Frequency section).
- A 3-cm depth target will be reached using an out-of-plane 45 degree angle approach if the needle insertion site is 3 cm away from the middle of the transducer/ultrasound beam (because both sides of an equilateral right angle or 45°-45°-90° triangle are the same length).
- Experienced ultrasound interventionalists are aware of or utilize triangulation principles for each injection.

"Walk-Down" Technique (Fig. 4.24)

- Utilized in out-of-plane injections.
- While staying below the skin, the needle is sequentially advanced, withdrawn, and redirected or "walked-down" to a slightly deeper position until it reaches the target.
- As soon as the needle appears on the screen (seen as a bright white dot), it must not be advanced further because there is no way of telling apart its tip from its shaft in the short axis view.
- Care must be taken when advancing the needle beyond where it is initially visualized out-of-plane since the true location/depth of the needle tip cannot be known.
- Some interventionalists incorporate calculated triangulation principles (see above) and are able to reach the target or get very close to it on the first attempt, eliminating the need for the walk-down technique.

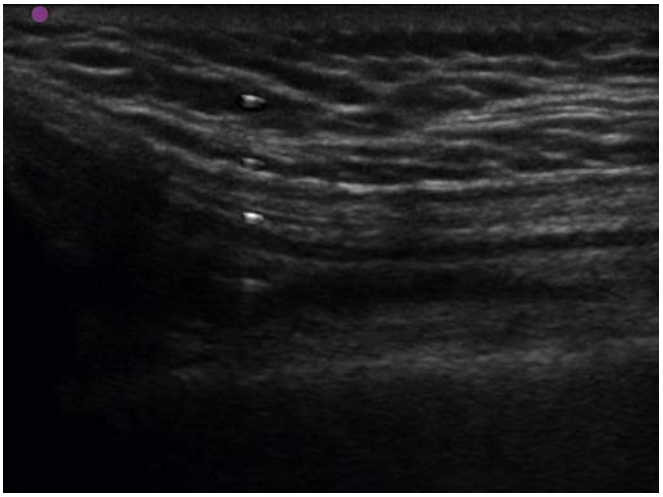


Fig. 4.24. Simulation of the walk-down technique in a short axis view created by the superimposed images with varying needle depth. Note the successively increased depth of penetration indicated by deeper location of the white dot (indicating the needle tip).

Scanning Technique Utilizing Needle Bend (Fig. 4.25)

- An accentuated bend in the needle tip effectively increases the diameter at its end. When rotated, the effect is similar to a propeller.
- This displaces a wider segment of tissue under the ultrasound transducer and may improve localization of the needle tip.
- This also allows for improved steering of the needle.
  - Steering to deeper structures is acheived with the bevel up.
  - Steering to shallower structures is achieved with the bevel down.

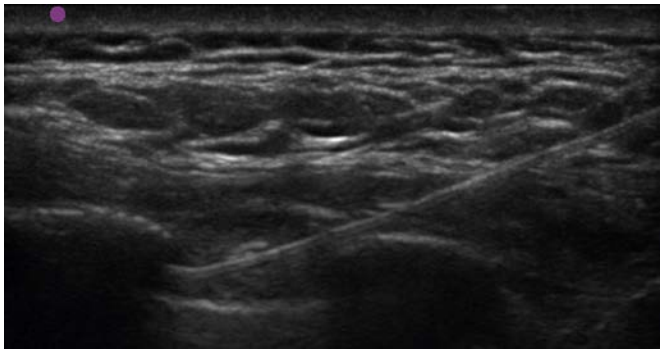


Fig. 4.25. A bent needle is utilized to accentuate steering of the needle tip to the structure of interest. This demonstrates a bent needle accessing the superior rib in an ultrasound-guided intercostal nerve block. (Chapter 2 describes bevel control with a bent needle.)

Hydrodissection (Fig. 4.26A, B)

- Injection of local anesthetic and/or saline allows for distinct identification of the needle tip and can be used to separate tissue planes along the needle path.
- Utilized for separating scarred-down and adherent structures, painful nerves, or peritendinous neovessels, especially around the Achilles tendon.
- Effectiveness is unproven despite its current popularity.

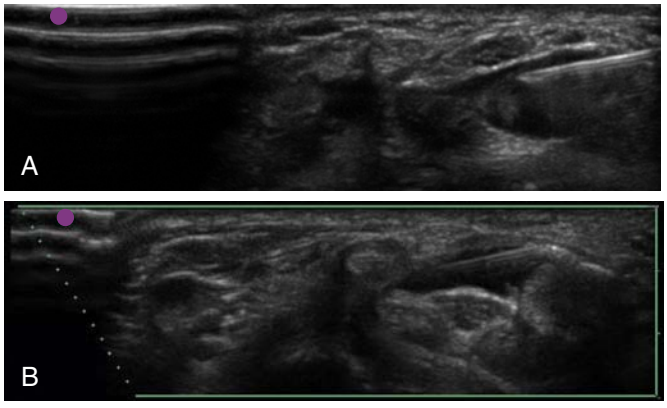


Fig. 4.26. A, Image of a needle deep to the median nerve, during hydrodissection. **B,** Image of a needle superficial to the median nerve during hydrodissection. Hydrodissection is used to displace the tissue, verify position of the needle tip, and separate the structure of interest (median nerve) from the surrounding tissue.

Shaken/Turbulent Injectate for Air Contrast (Fig. 4.27A, B)

- Mixing the injectate with a little air by shaking it creates echogenic microbubbles, which function as an ultrasonic contrast agent, useful for assessing flow into joints and other spaces.
- Excessive air (like too much radiologic contrast) can obscure the view.

Confirming the Anatomic Level with Ultrasound

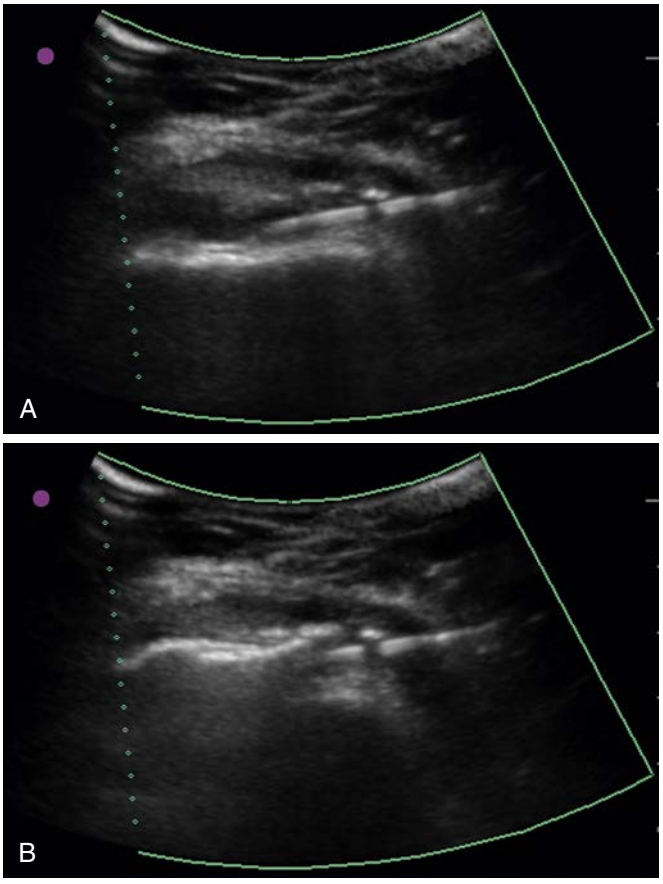


Fig. 4.27. A, An ultrasound image prior to the injection of shaken injectate. **B,** An ultrasound image after injecting the shaken injectate with microbubbles. Note the hyperechoic signal and acoustic shadowing deep into it.

CERVICAL SONOANATOMY (FIGURES 4.28 TO 4.32)

Method 1: Coronal View—Counting Cervical Vertebrae

- Evaluation can be started in the lateral aspect of the neck, with a linear probe in a coronal orientation (Fig. 4.28A).
- The transducer can be moved anteriorly until the transverse processes (Fig. 4.28B) are visualized and moved posteriorly until the facet joints and facet joint capsules are identified (Fig. 4.28C).

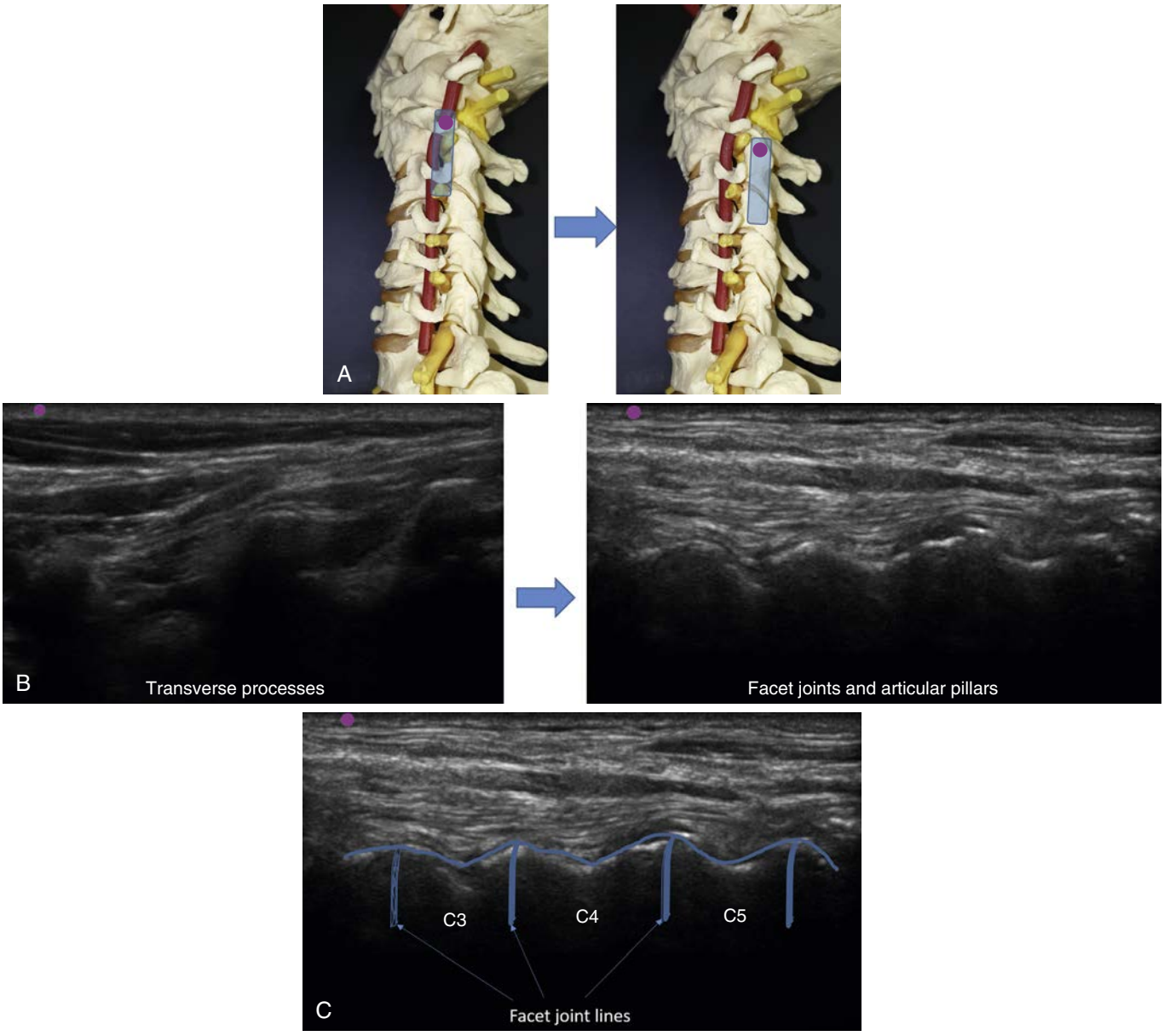


Fig. 4.28. A, A cervical spine model demonstrating initial placement of the ultrasound transducer (shaded rectangle) over the lateral cervical spine in long axis (sagittal view). Identify the transverse processes in the sagittal plane (see also Fig. 4.29B), and translate posteriorly to identify the cervical facet joints. **B,** Ultrasound images that correspond to Fig. 4.29A. Initial placement of the ultrasound should identify the transverse process (left). Translate posteriorly to visualize the facet joints (right). **C,** An ultrasound image of the facet joints. Notice the undulating contour between the joints, which form "peaks and valleys." The "peaks" are the location of the opening of the joint space, and occasionally the facet joint capsule can be identified. The "valleys" are midpoint (aka waist) of the articular pillar, where cervical medial branch nerves can be found in certain vertebrae. The dropoff at C2-C3 is on the left of the screen and is not well visualized.

- Once the articular pillars and facet joints are clearly visualized, translate cephalad to visualize the anatomic landmarks used to identify the C2-C3 joint. Immediately cephalad to the C2-C3 facet joint, there will be a steep dropoff, as the next joint (C1-C2) lies slightly more midline and anterior in relation to the other facet joints. This bony "dropoff" can be used as an anatomic landmark for identifying the C2 and C3 vertebrae (Fig. 4.29A). In addition, the vertebral artery is exposed at the anterolateral aspect of the C2 vertebrae, and the use of Doppler can facilitate in identifying this important vessel at C2.
- Posterior evaluation with a curvilinear probe may be helpful in that it may allow one to see all cervical levels in one wide-angle view (Fig. 4.29B).

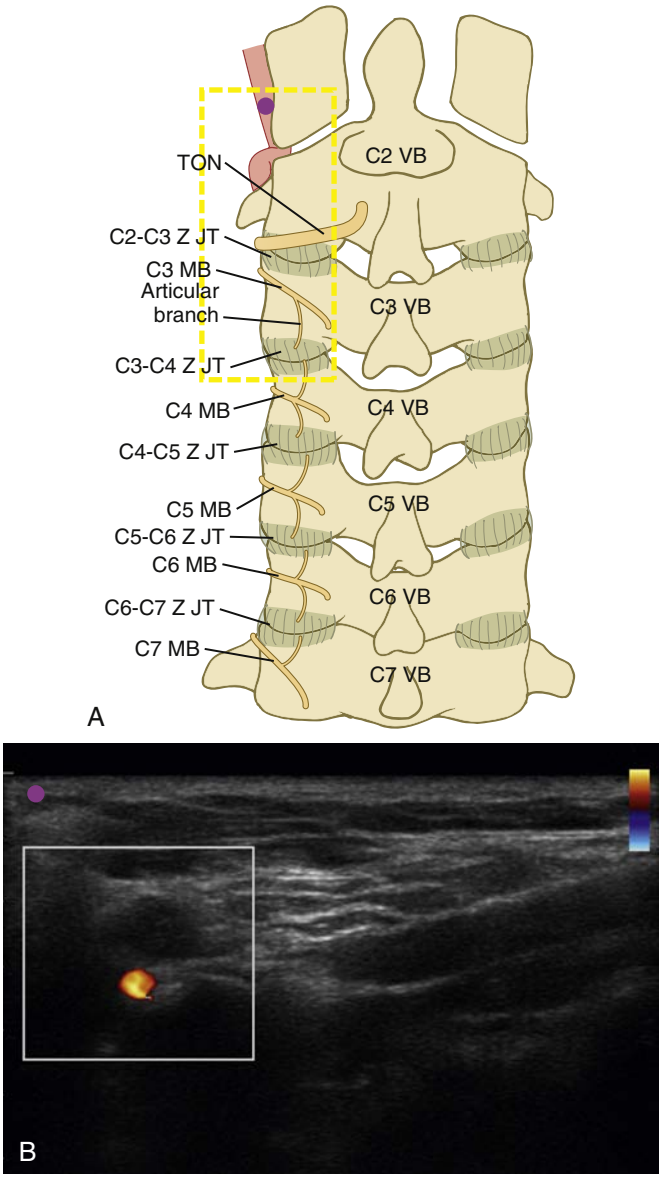


Fig. 4.29. A, Cartoon representation of the cervical spine with the ultrasound transducer placed posteriorly. The vertebral artery ascends along the anterolateral cervical spine through the vertebral foramen of C6 to C3, after which it courses superolaterally to enter the C2 transverse foramen, which is oriented in a more sagittal plane. After coursing through the C2 foramen, it continues posterolaterally to pass through the transverse foramen of C1 (atlas). Placing the Doppler just cephalad to the C2 vertebral body can help visualize the vertebral artery as it courses between the C2 and C1 vertebrae, helping to verify the current level under ultrasound. **B,** Enabling the Doppler function and placing the focus over the anatomic dropoff cephalad to the C2 vertebrae should identify the vertebral artery (red). Slight anterior translation may be needed to better visualize the artery as it courses from the C2 vertebral foramen to the C1 vertebral foramen.

Method 2: Axial View—Identifying the C6 Vertebrae via Chassaignac's Tubercle (Prominent Anterior Tubercle of the C6 Transverse Process)

- Using an axial view, the evaluation can be started, with the transducer moving anteriorly over the midline structures, identifying the thyroid gland, carotid artery, and jugular vein (Fig. 4.30A).
- Moving the transducer laterally, the vertebral bodies/cervical discs are seen, followed by the transverse processes of the cervical vertebrae (Fig. 4.30B). The transverse processes of C2-C6 are bifid, with an anterior and a posterior tubercle, whereas C7 only has a posterior tubercle.

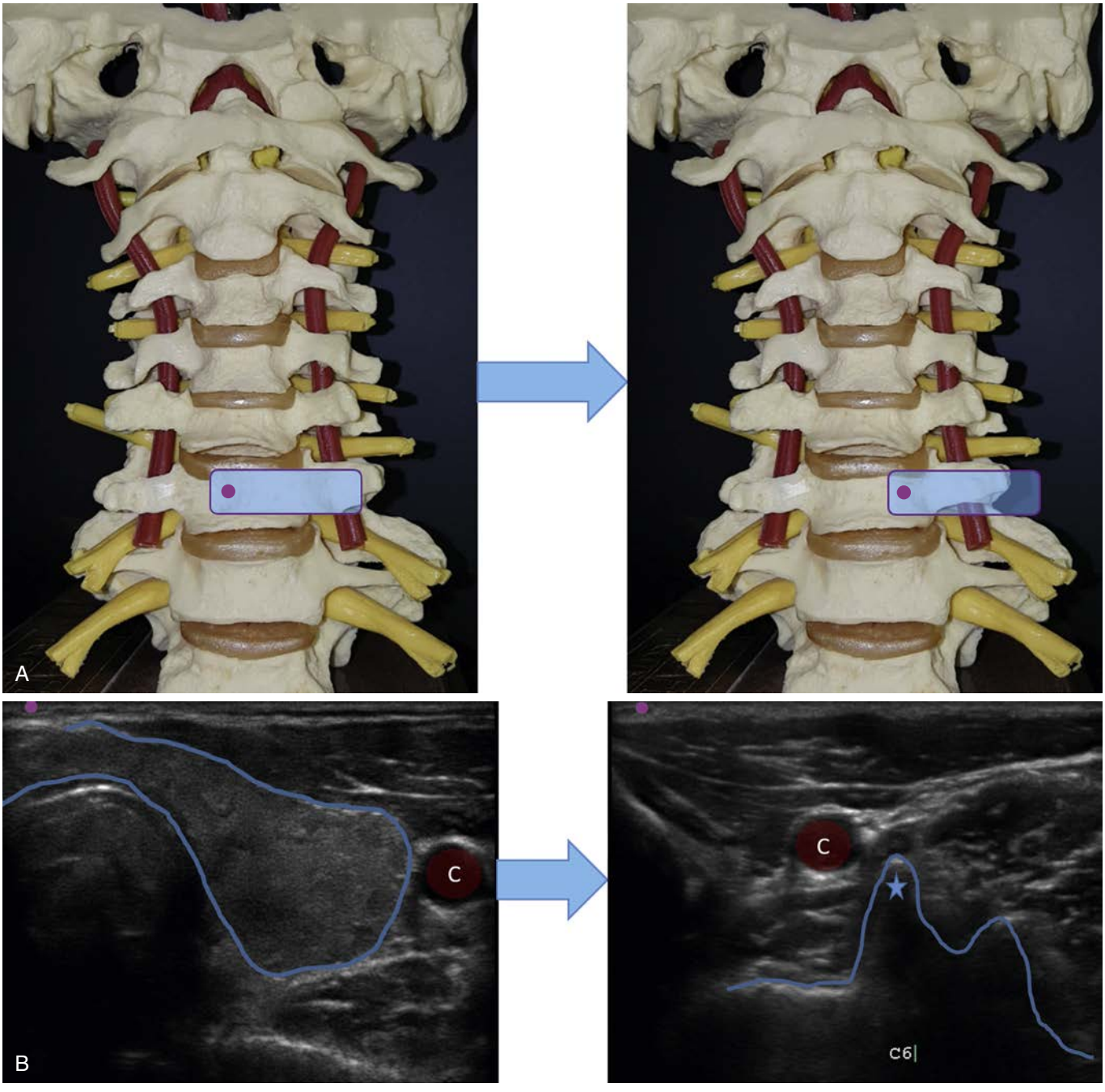


Fig. 4.30. A, A cervical spine model demonstrating the initial placement of the ultrasound probe (shaded rectangle) over the anterior neck in the axial plane (short axis). Start with placement anywhere below the laryngeal prominence of the thyroid cartilage (i.e., Adam's apple), and scan inferiorly/caudally until the thyroid gland is visualized (which typically lies anterior to the C6 or C7 vertebrae). Next, translate laterally until the transverse processes come into view. **B,** Ultrasound images that correspond to the above description. The thyroid gland is outlined in blue in the left image. Translating lateral will reveal the transverse processes; in this case, the C6 transverse process is seen in the right image (outlined in blue). The blue star identifies the large anterior tubercle of the C6 vertebrae (Chassaignac's tubercle), which is an important landmark in helping identify the level. **C,** Carotid artery.

- This anatomic change between the C6 and C7 vertebrae can be used to identify the current vertebral level under ultrasound, but a more common anatomic landmark is the prominent anterior tubercle of the C6 transverse process (Fig. 4.31A).
- The prominent anterior tubercle at the C6 transverse process is known as Chassaignac's tubercle (aka the carotid tubercle).
- The C7 vertebral body can also be identified using Doppler to visualize the vertebral artery, which is exposed at that level. Generally, the vertebral artery lies anterior to the C7 transverse process, and as it ascends, it dives deep to enter the foramen transversarium of the C6 vertebrae. However, there are anatomic variations to the vertebral artery at this level, as sometimes it is located within the C7 foramen transversarium.
- By using these anatomic landmarks, one can determine the current vertebral level, and the transducer can be moved cephalad counting each level thereafter (Fig. 4.31B, C).

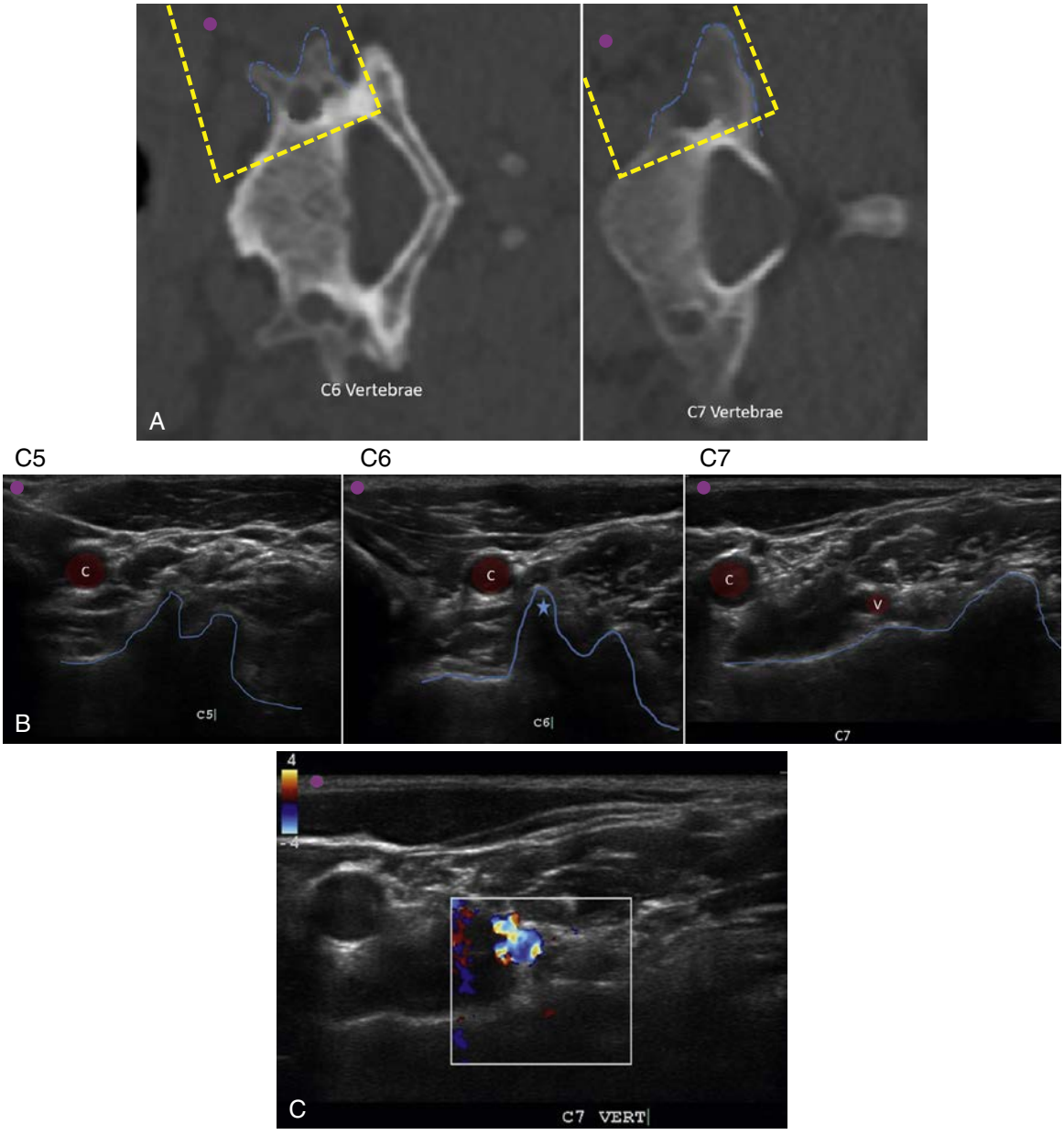
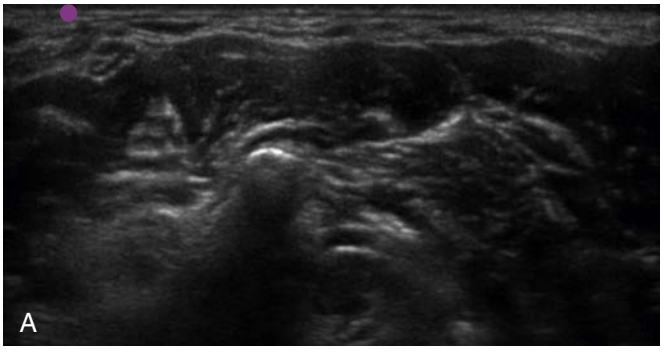
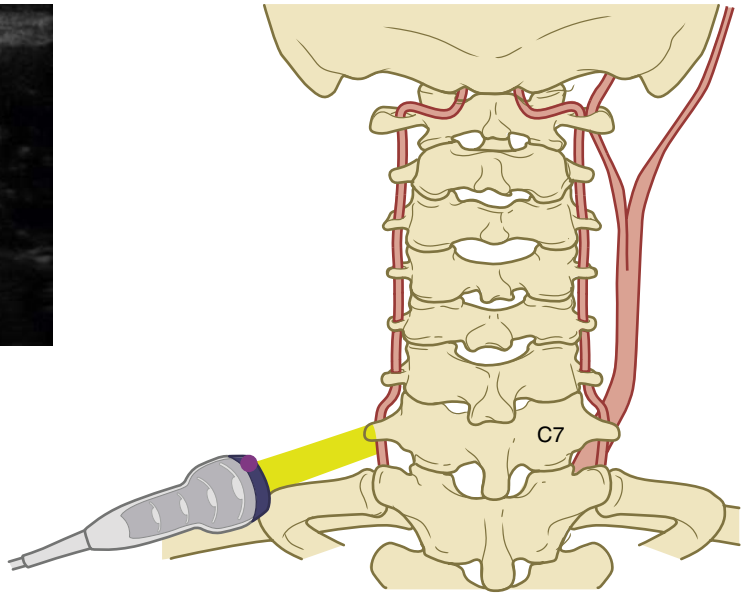
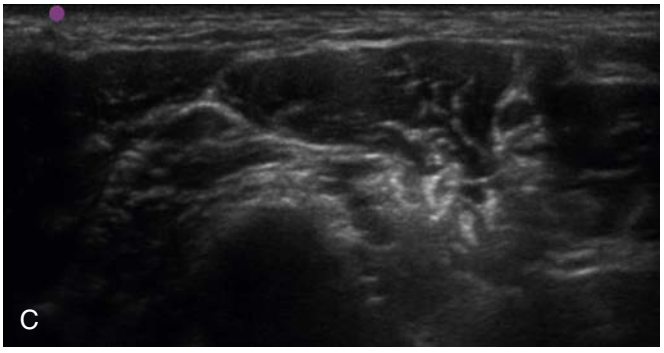


Fig. 4.31. A, Computed tomography axial comparison of C6 and C7 vertebral bodies. Notice the bifid transverse process of C6 vertebra (red), whereas C7 only has a posterior tubercle (red). Also notice how the C7 transverse process is more posterior compared to the C6 transverse process. The yellow dashed rectangles represents the field of view when using ultrasound. **B,** Ultrasound images comparing the C5, C6, and C7 transverse processes. The C5 transverse process typically has relatively equal-sized anterior and posterior tubercles. The C6 transverse process typically has a significantly larger anterior tubercle (labeled with a star) compared with C7, which has the posterior tubercle. The C7 transverse process is not bifid (only has a posterior tubercle), and the vertebral artery is also exposed at this level. Notice the location of the carotid artery in all pictures, and the exposed vertebral artery at the level of the C7 vertebrae (the vertebral artery does not traverse the vertebral foramen of the C7 vertebra but instead lies anterior to the posterior tubercle in a majority of the population). **C,** An ultrasound image with the Doppler activated to demonstrate the location of the exposed vertebral artery. Compare its location to the larger carotid artery located more anteriorly on the left.







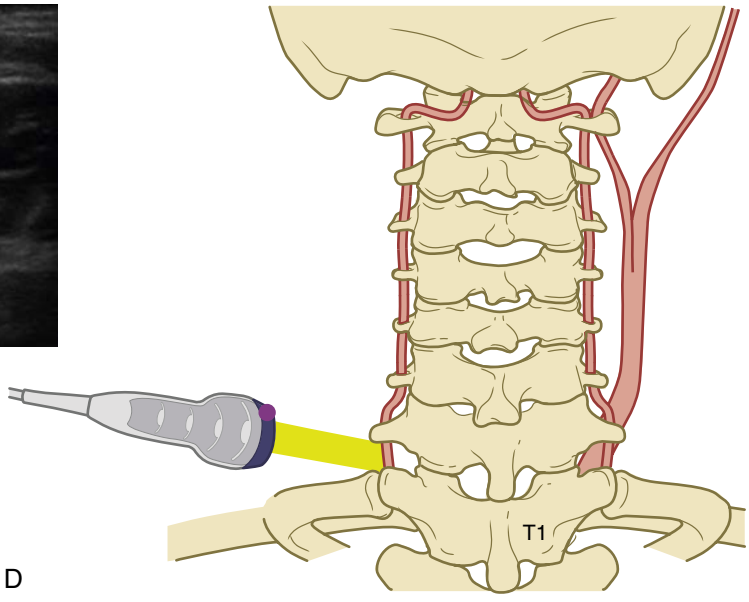


Fig. 4.32. A, An ultrasound image of the lateral aspect of the C7 vertebral body in short axis to the neck. Notice the prominent transverse process of C7 compared to the T1 vertebrae (see Fig. 4.32C). Its location is also more anterior when compared to the T1 transverse process. Once the C7 transverse process is identified, caudal tilt will visualize the T1 transverse process; alternating back and forth between these views will help distinguish these features. **B,** Cartoon representation corresponding to the previous Figure 4.32A demonstrating the easily identifiable landmarks including the transverse process, vertebral body, and carotid artery. **C,** An ultrasound image of the lateral aspect of the T1 vertebral body in short axis to the neck (axial view). The T1 transverse process is not as prominent and is situated more posterior than the C7 transverse process. **D,** Cartoon representation corresponding to Figure 4.32C demonstrating how changing the tilt of the probe can visualize the T1 transverse processes, by simply changing the transducer orientation in short axis to the neck.

Method 3: Axial View—Determining Level by Identifying the T1 Transverse Process vs. the C7 Transverse Process

- Evaluation can also be started in the lateral aspect of the neck with identification of the T1 and C7 transverse processes, and counting can be started cephalad from that point onward. The T1 transverse process will be more posterior in relation to the C7 transverse process.
- By tilting the probe cephalad, then caudally, one can identify both the C7 transverse process (Fig. 4.32A, B) as well as the T1 transverse process (Fig. 4.32C, D) and possibly the costovertebral joint.

LUMBOSACRAL SONOGRAPHY

Axial Evaluation

Examination can be started at the median sacral crest, with identification of the bilateral S1 foramina, the most superiorly visualized sacral foramina, before visualizing the prominent spinous process of the L5 vertebrae. Also note the posterior superior iliac spine (PSIS) as well as the superior aspect of the sacroiliac joint (Fig. 4.33).

To begin counting the lumbar vertebrae, the transducer can be moved cephalad until the spinous process of L5 is identified and the counting can continue in a cephalad manner, until the thoracolumbar junction is identified. Plain films should always be used to correlate, especially with transitional vertebrae; see Chapter 3 for more discussion on transitional segmentation (Fig. 4.34A to C).

Upon visualization of the spinous process at the desired level, the transducer can be moved laterally to identify the facet joints and transverse process. This view can be used for facet joint injections or medial branch blocks (Fig. 4.34D).

For anatomic review, the medial branch nerves are located at the bony notch between the superior articular process and transverse process (L1-L4) or the S1 superior articular process and sacral ala (L5 dorsal ramus).

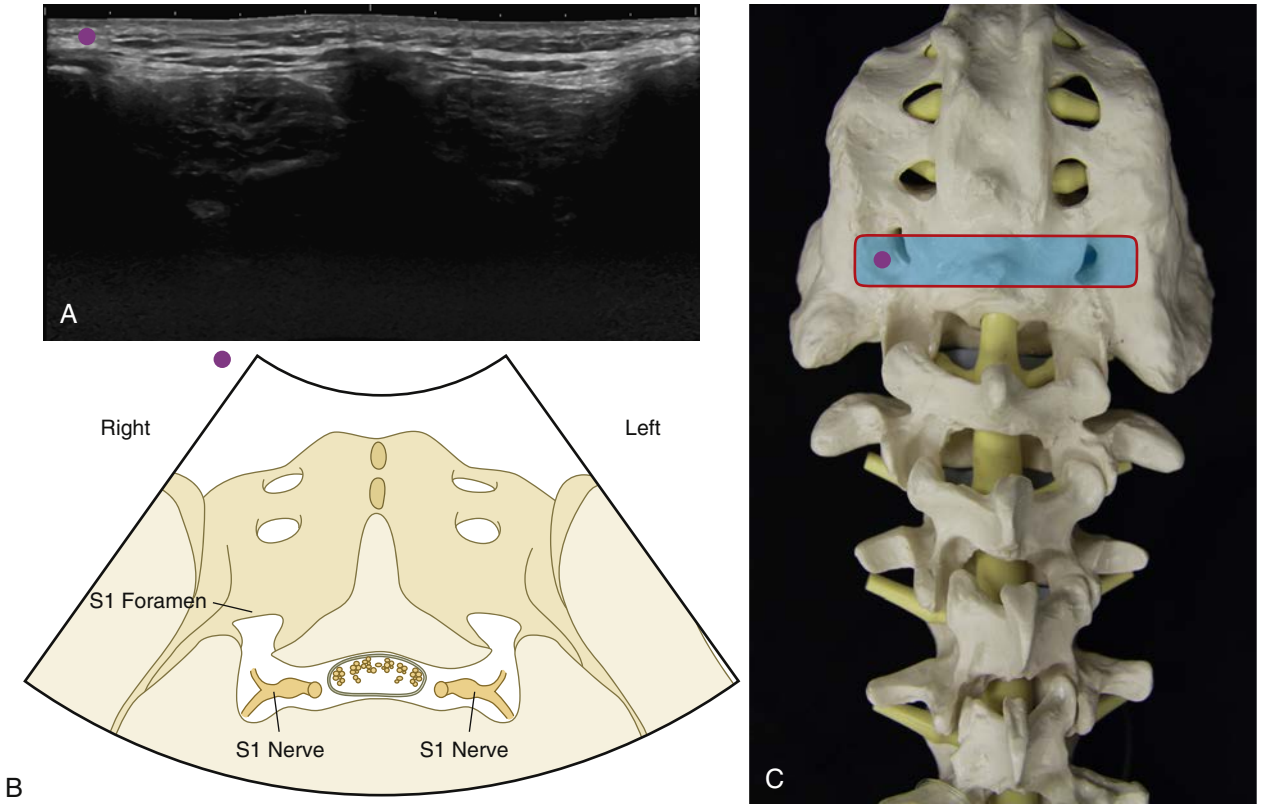


Fig. 4.33. A, An ultrasound image of the sacrum at the level of the S1 foramen in short axis (axial view). Notice how the sound waves penetrate into the foramen, making them easier to identify. Adjusting the tilt of the probe is needed to optimize the foramen. **B,** Cartoon representation corresponding to the previous figure, demonstrating visible landmarks such as the spinous process, superior aspect of the sacroiliac joint, and posterior superior iliac spine. Special attention should be paid to the location of vital structures that are not clearly seen via ultrasound: the S1 nerve roots, epidural space, and descending nerve roots in this case. **C,** Skeleton demonstrating proper placement and orientation of the curvilinear ultrasound probe.

The counting of the lumbar vertebrae can also be done in the parasagittal view. This view can be obtained by placing the transducer in a sagittal orientation, directly over the spinous processes. The transducer can then be swept laterally until the Z joints and/or transverse processes are identified. The sacrum serves as the landmark for counting, so, if needed, the transducer can be moved caudally until the sacrum is identified. Once the sacrum is identified, the counting of adjacent transverse processes can begin from that point cephalad (Fig. 4.35A to C).

The transducer can be moved caudally from the S1 foramen to visualize the S2 foramen, as well as the posterior inferior iliac spine and sacroiliac joint. Sacroiliac joint injections via ultrasound are typically done at the level of the S2 foramen (see Chapter 10B) (Fig. 4.36A to C).

Further caudal migration with the ultrasound probe will reveal the sacral hiatus and the two sacral cornua that protrude dorsally on either side of the hiatus. The sacral hiatus is an opening into the sacral spinal canal, which is continuous with the lumbar spinal canal and epidural space. This is a useful entry point for epidural injections (Fig. 4.37).

Further caudal migration of the ultrasound probe will reveal the sacrococcygeal disc. This is useful for accessing the region of the ganglion impar.

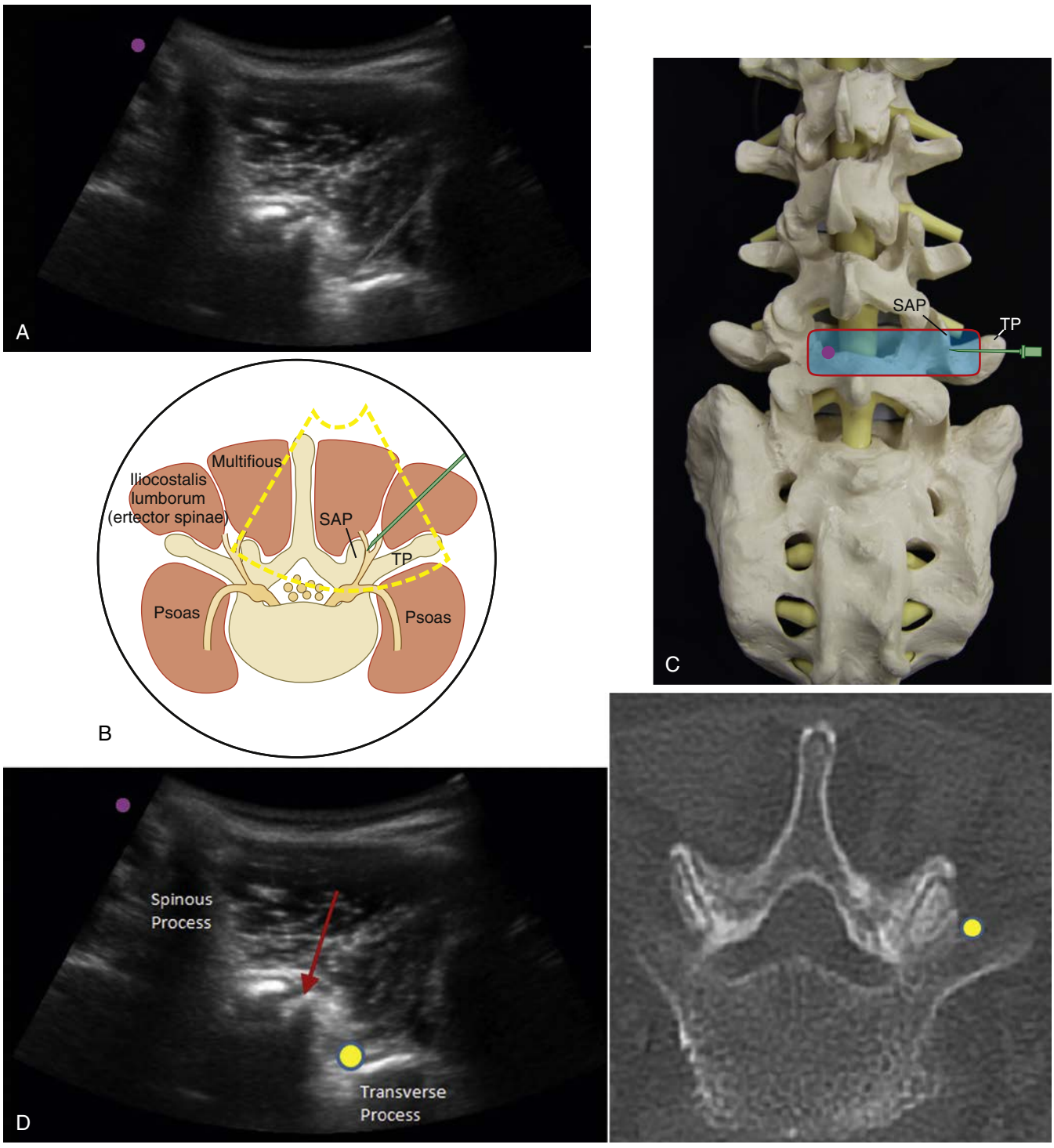


Fig. 4.34. A, An ultrasound image of the posterior elements of the L5 vertebral body in short axis (axial view). **B,** Cartoon representation corresponding to the previous figure. Special attention should be paid to the location of the vital structures that are not clearly seen via ultrasound: the epidural space and descending nerve roots in this case. **C,** Skeleton demonstrating proper placement and orientation of the ultrasound image shown in Fig. 4.35A. **D,** An ultrasound image of the posterior elements of the L5 vertebral body, including the spinous process, facet joint (red arrow), and transverse process. The yellow dot represents anatomic locations of the descending medial branch, in this case, the L4 medial branch. Adjacent to the ultrasound image is a corresponding computed tomography scan image of a lumbar vertebral body.

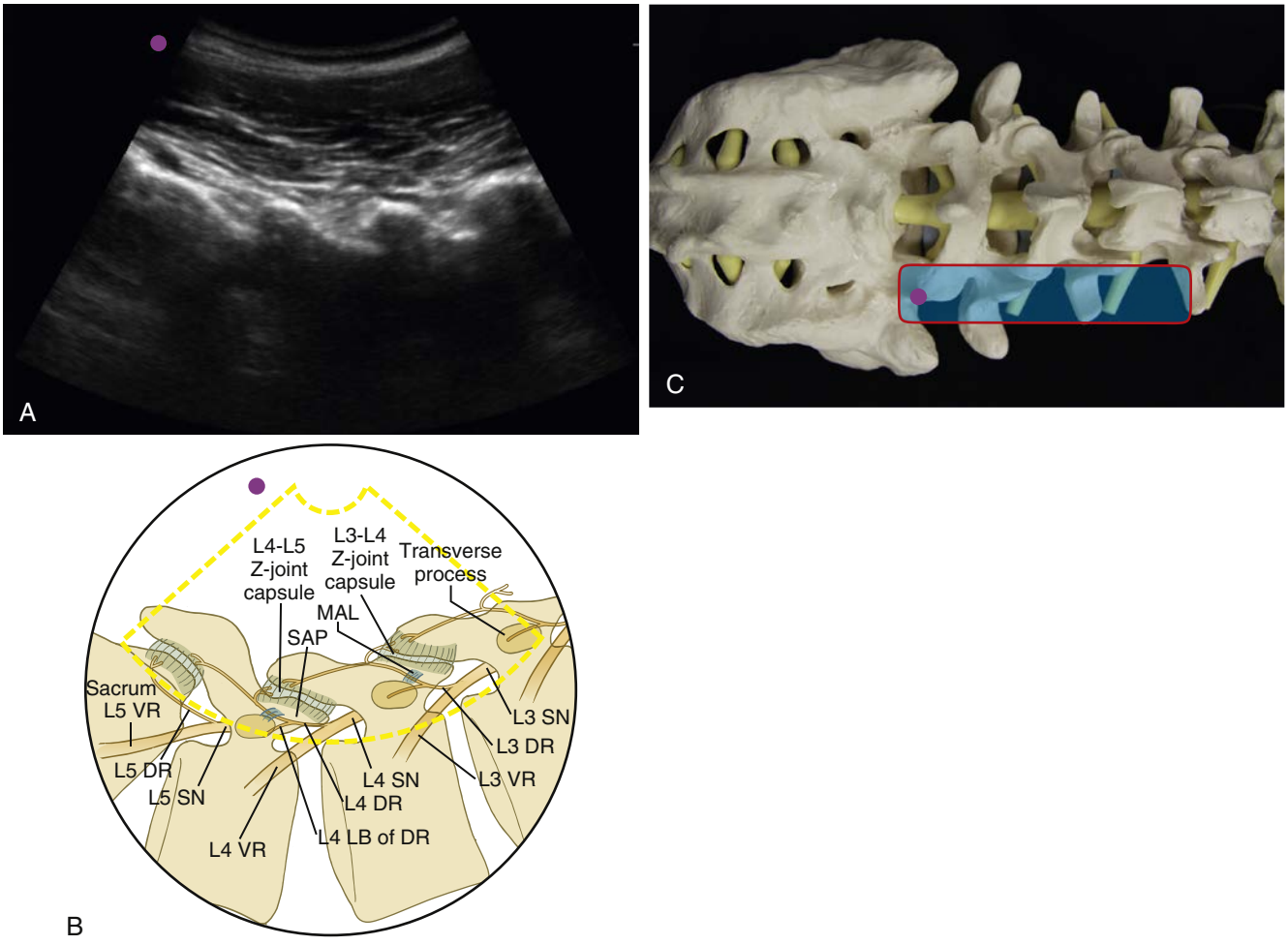


Fig. 4.35. A, An ultrasound image demonstrating the lumbosacral spine in long axis (sagittal view), overlying the transverse processes. The transverse processes can all appear similar, but try to identify the sacral ala to allow accurate identification of the other lumbar levels. **B,** Cartoon representation corresponding to the prior figure, demonstrating vital structures that are not clearly seen via ultrasound, which in this case are mainly the nerve roots. **C,** Skeleton demonstrating proper placement and orientation of the ultrasound probe.

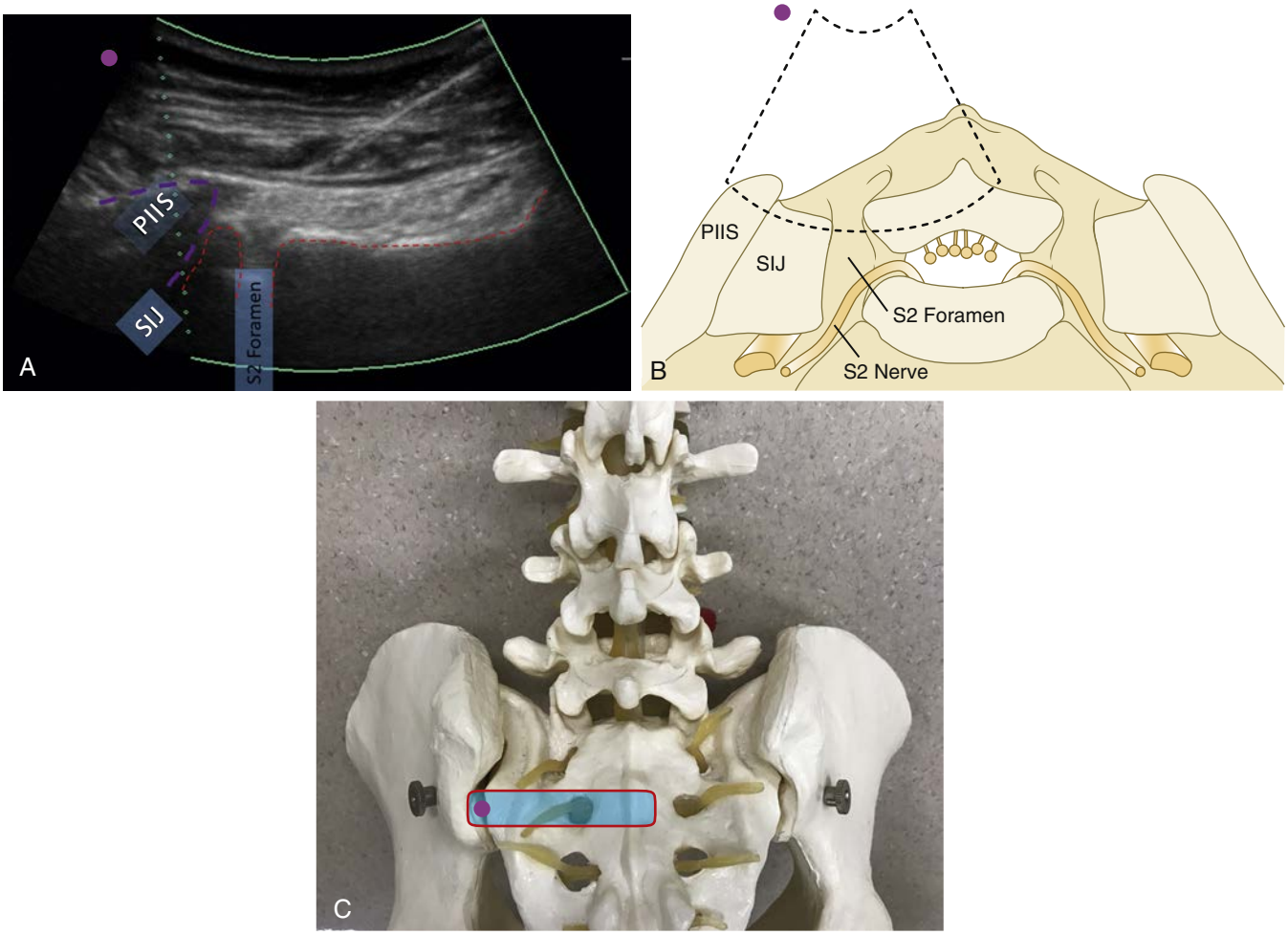


Fig. 4.36. A, An ultrasound image of the sacrum at the level of the S2 foramen in short axis (axial view). The foramen can be readily visualized as it allows penetration of sound waves. To best optimize the foramen, tilt the transducer until the sound waves align with the foramen. The sacroiliac joint and posterior inferior iliac spine can also be visualized at this level. **B,** Cartoon representation of relevant structures that correspond to previous ultrasound image. **C,** Skeleton demonstrating proper placement and orientation of the ultrasound transducer.

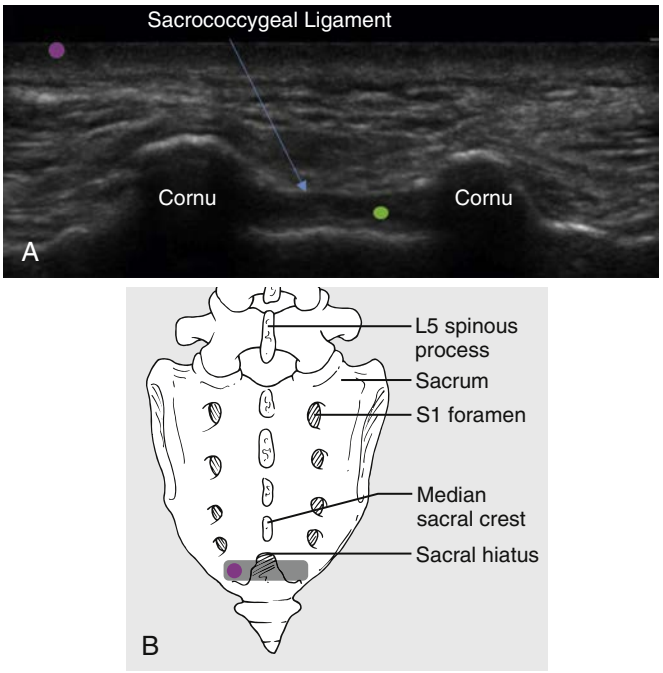


Fig. 4.37. A, An ultrasound image of the sacral hiatus in short axis (axial view) and the anatomic landmarks that help identify its location under ultrasound. The green dot represents a needle in the epidural space seen out-of-plane. **B,** Anatomic drawing of the sacrum. The rectangle represents the placement of the ultrasound transducer that corresponds to Fig. 4.37A. Chapter 7C contains more information regarding USG caudal ESIs.

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CHAPTER 5

Optimizing Patient Safety and Positioning

Sarah Hagerty, Nicholas H. Weber, Julie M. Grove, and Michael B. Furman

"Danger is my middle name."
AUSTIN DANGER POWERS

"Safety is my middle name."
Sarah *Safety* Hagerty
Nicholas *Safety* Weber
Julie *Safety* Grove
Michael *Safety* Furman

INTRODUCTION

Setup is key.

Setup pertains to not only the fluoroscope and needle positioning but also the procedure room, tray, and patient. Attention should be paid to ensure that the patient is in a position of comfort during any interventional procedure and to set up the procedure room to optimize safety, efficiency, and clear image acquisition.

With the new initiative linking patient satisfaction scores with reimbursements, the patient's perception of a procedure must also be respected. Patient comfort is the key to satisfaction of the procedure. Simple comfort measures can decrease patient anxiety and the risk of secondary pain/injury related to positioning.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

PREPROCEDURE

Prior to the procedure day, the staff should review the chart to:

- Confirm that the ordered procedure matches the instructions given in the last visit note including laterality (side) and level.
- Identify potential unidentified procedural concerns, including but not limited to anticoagulation or antiplatelet medications, coagulation or other medical issues, allergies, transitional segment, previous vasovagal event, and procedural issues.

INTRAPROCEDURAL SAFETY

Marking the Correct Procedure Side (Fig. 5.1)

- The Joint Commission Universal Protocol[1] suggests that the spinal procedures surgical site mark be placed in the general skin area. The actual marking may vary, but the following guidelines can be used:
  - The mark should be unambiguous and consistent throughout the organization.
  - The American Academy of Orthopaedic Surgeons recommends including the provider's initials[2].
  - We further suggest that the mark include procedural side with "L" or "R" and/or an accompanying arrow.
  - In the case of midline or bilateral procedures, such as interlaminar epidural steroid injections, include the side with the majority of the symptoms (e.g., Left > Right).
  - After skin preparation and draping, the mark should still be visible.
  - In Figure 5.1, the physician's initials, the spinal level, and laterality are shown.
- Confirming the details with the patient while site marking and confirming with skin preparation improves accuracy, eases patient anxiety, and improves perception of a safe environment.

Fig. 5.1. Marking the patient with correct procedure site, including physician's initials, procedure, and laterality. Content of marking depends on local policy.

Procedure Time-Out/Proper Site Board (Fig. 5.2)

- Patient and all team members stop what they are doing and participate in the "time-out." The patient verbally states his or her name and date of birth and confirms the procedure, side, and level.
- Put visual cues on a whiteboard that is placed in view throughout the procedure and in close proximity to the fluoroscope or ultrasound screen, to continually remind the interventionalist regarding the side, level, and type of procedure, as well as any other pertinent factors such as the following:
  - Allergies to medications typically used in procedures (contrast, antibiotic, anesthetic, latex, etc.)
  - More symptomatic side if bilateral or midline procedure is to be performed
  - Names of the physician performing the procedure, nurse present in the room, and referring physician (optional information)
- However, one should avoid putting excess information on the whiteboard, as this may result in less emphasis on the information most vital to the procedure.

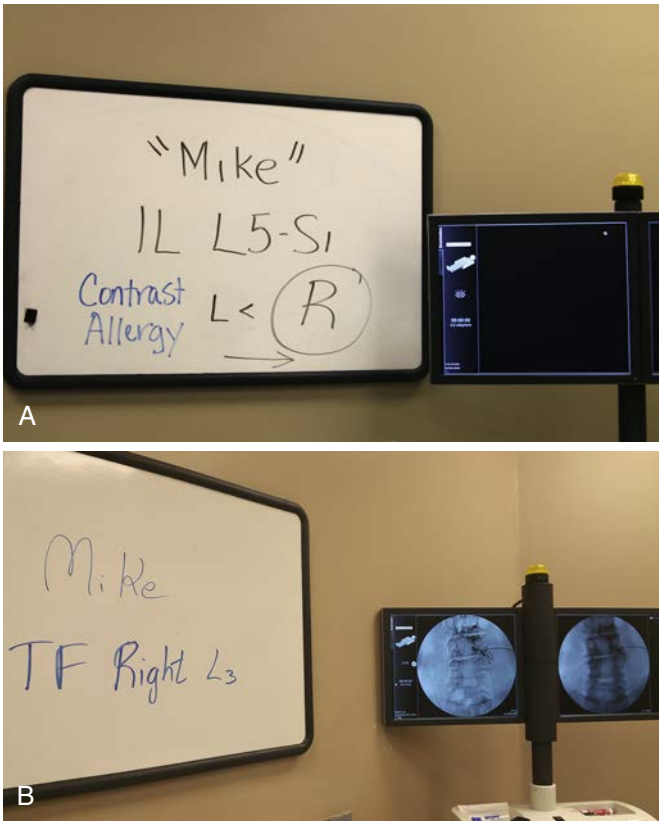

Fig. 5.2. A, Example of a visual cue whiteboard showing patient details, procedure followed, and other important patient variables. **B,** Example of a visual cue whiteboard (with identifying information) positioned alongside the fluoroscopy screen to assist with the patient time-out and constant intraprocedure confirmation. Having the whiteboard next to the fluoroscopy screen provides a real-time visual reminder to avoid a wrong-site or wrong-side procedure.

Use of the C-Arm (Fig. 5.3)

- The C-arm should be set up so that it is easier to navigate once the procedure begins, with efficient adjustments made when needed (Fig. 5.3A).
- It is optimal for the pistoning (see Chapter 3 for further details on right/left, medial/lateral translation) to be set up in a neutral/midline position (Fig. 5.3B) once the target is identified.
- It is suboptimal for the pistoning to be in any extreme position (Fig. 5.3C) since this makes fine-tuning more difficult.

Fig. 5.3. A, Placement of C-arm in simulated patient. **B,** Zoomed in C-arm picture of the optimal piston starting setting (in neutral position). This allows the C-arm to be moved with ease for fine-tuning during the procedure (translation or pistoning of the image intensifier without complete lateral translation of the C-arm base). **C,** Suboptimal position of C-arm when starting procedure. Beginning at the extreme end of either of the positions causes excess movement of the C-arm during the procedure.

Monitoring Vital Signs

- Provides real-time recording of the heart rate, oxygen saturation, and other vital signs throughout the procedure.

Supplemental O_2 via Nasal Cannula

- May provide a level of comfort during the cervical spine procedures for patients positioned prone on a cervical board or supine with a sterile drape partially covering their face.

Monitoring Cases During Intravenous Sedation

- Blood pressure, rhythm and heart rate using electrocardiogram (ECG), and O_2 saturation level should be monitored.
- An additional dedicated nurse is needed to assist in monitoring vital signs and administration of pain-relieving and/or sedating medications.

PATIENT COMFORT

Squeeze Ball (Fig. 5.4)

- The procedure may cause stress or discomfort to the patient. The squeeze ball acts as a source of distraction for patients during times of discomfort, needle movement, medication injections, or anxiety.

Fig. 5.4. Squeezable object or ball to reduce intraprocedure stress.

PATIENT POSITIONING

Prone

- Used for the majority of spinal procedures.
- The optimal positioning for cervical procedures will include placing a cervical board when needed. The ideal position for the patient's forehead is at the top of the headrest with the chin tucked fully to the chest (Fig. 5.5A). This allows for a slightly flexed cervical position with minimal shoulder retraction. The patient's arms are ideally at the side (unless they may obscure an image) and relaxed with a safety "reminder" strap in place.
- Suboptimal positioning will include positioning without neck flexion or excess neck extension (Fig. 5.5B). Also, if the patient's arms are resting above his or her head, it may obscure imaging, particularly when obtaining cervical contralateral oblique or lateral images, as the shoulders may superimpose the structure of interest.
- Virtually, thoracic procedures have the same setup. However, the pillow is placed more cephalad so that it is under the patient's chest with the pillow edges near his or her shoulders. Procedures performed in this position include thoracic interlaminar and transforaminal epidural steroid injections, thoracic medial branch blocks and radiofrequency ablation, and intercostal nerve blocks. Arms are positioned such that they do not obscure lateral imaging.
- A suboptimal position is a position that results in thoracic extension or prevents optimal visualization and/or procedure performance.
- The prone position is utilized for lumbar interlaminar epidural steroid injections, transforaminal epidural steroid injections, lumbar facet joint injections, lumbar medial branch blocks and radiofrequency ablation, discography, and myelograms, as well as for spinal cord stimulator trials.
- Optimal positioning will include two pillows under the patient's abdomen to flatten the lordosis (Fig. 5.7A). A pillow under the patient's ankles provides comfort and also decreases the contraction of lumbar paraspinal muscles that can accentuate the lordosis. Placing the patient's arms off the table above the waist or arms resting under the head is also preferred.
- Suboptimal positioning includes the placement of pillows under the shoulders or head rather than under the abdomen, which will result in an exaggerated lumbar lordosis (Fig. 5.5D).
- The prone position is also utilized for sacroiliac joint injections, caudal epidural steroid injections, and ganglion impar blocks.
- Optimal positioning will include pillows positioned low under the abdomen and pelvis, in line with the hips, with the feet ideally turned inward asking the patient to actively internally rotate at the hips to relax the external rotators.
- Suboptimal positioning will include placing a pillow under the patient's head, with feet pointed outward.

Side-Lying/Lateral

- Utilized in cervical zygapophyseal (facet) joint injections or cervical medial branch blocks.
- Optimal positioning includes placing a cervical pillow with the neck in a neutral position in the flexion, extension, and coronal planes (preventing side-bending). Additional stability in this cervical neutral position may be achieved by utilizing a triangle wedge placed against the patient's upper thoracic spine, secured under the reminder strap. Arms are placed at the patient's side with the arm toward the table tucked under his or her body with the shoulders relaxed as much as possible in a depressed position. Patients will naturally elevate their shoulders, especially the side that is upright, so they should be informed and reminded not to do so while the physician is setting up the procedure (Fig. 5.6A).
- Suboptimal imaging is depicted in Fig. 5.6B.
- Side-lying position can be utilized in lumbar procedures as an alternative approach for lumbar interlaminar epidural steroid injections.
- It can also be used for intraarticular hip injection and for ultrasound-guided greater trochanteric bursa injection.

Supine

- The supine position is utilized for cervical transforaminal epidural steroid injections. It can also be used for cervical medial branch blocks, facet injections, and other procedures.
- Optimal positioning is achieved by placing the patient's head slightly turned to the contralateral side of the procedure, and the neck slightly extended with the "chin up" position (Fig. 5.6C).
- Suboptimal positioning is shown in Fig. 5.6D. Note that the neck is flexed, which engages the neck flexors, making the procedure more difficult and increasing the discomfort of the patient.

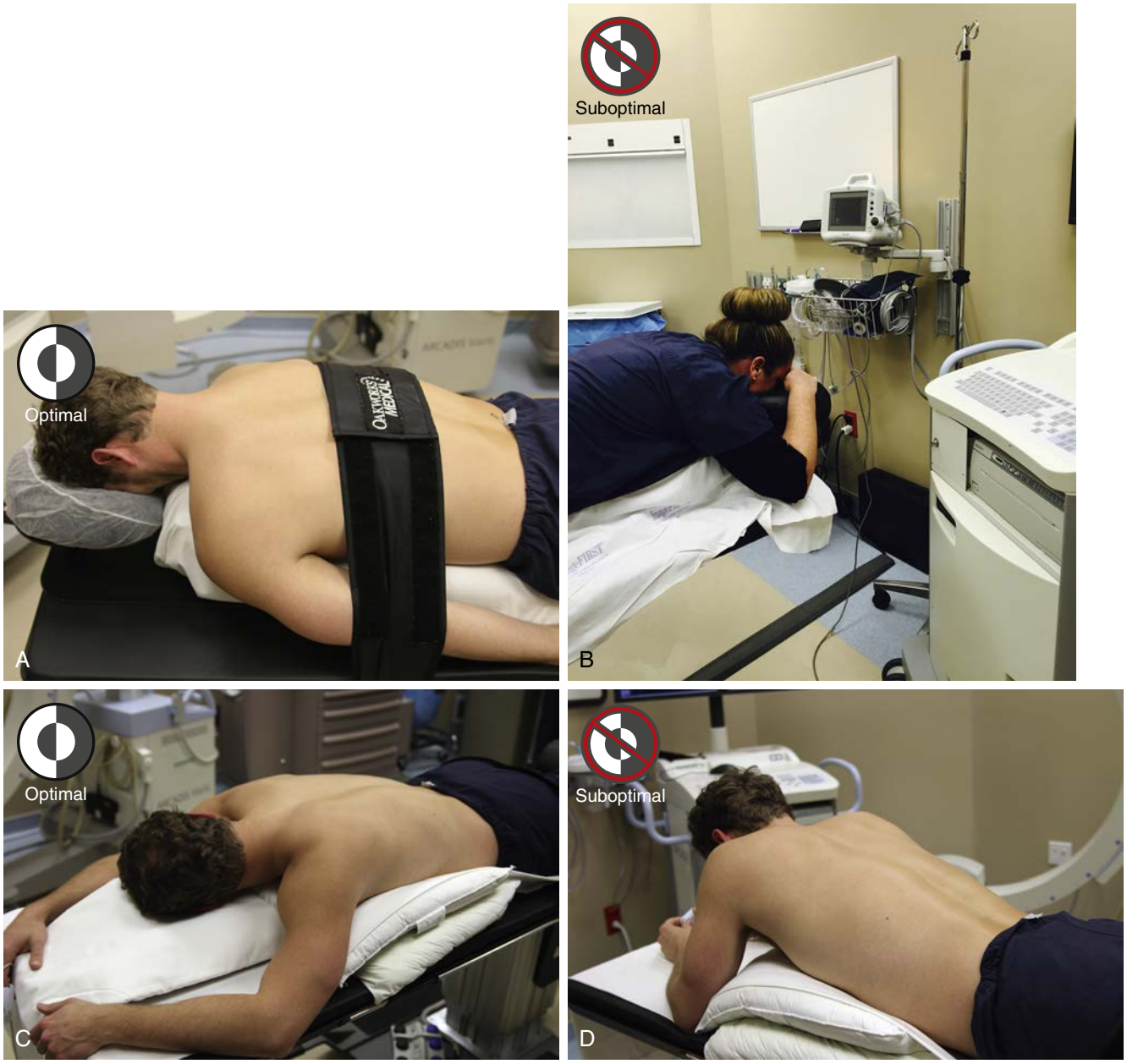

Fig. 5.5. A, Optimal position for cervical procedure in a prone position. Note that the patient's cervical extensor musculature is relaxed and his upper limbs are at his side. This allows for unobstructed cervical visualization, easier needle advancement, and improved patient tolerance. **B,** Suboptimal position of cervical procedures with the simulated patient in a prone position. The patient's neck is extended, shoulders obstructing the oblique or lateral imaging, and skin over the needle entry target not well visualized. In addition, cervical extensor musculature is activated, making needle entry and driving potentially more challenging. **C,** Optimal prone position of the patient with head relaxed on the pillow and no weight on the elbows. This is important for either thoracic or lumbar procedures. This helps to prevent contraction of paraspinal musculature, as compared to Fig. 5.5D. **D,** Suboptimal position of lumbar procedures with the patient in a prone position. Note how the patient is up, resting on his elbows, resulting in lumbar extensor musculature contraction.

Fig. 5.6. A, Optimal position for cervical procedures in the lateral position. Note that the cervical spine is in a neutral position with no lateral side-bending, flexion, or extension. **B,** Suboptimal position of cervical procedures in the lateral position, with the neck side-bending laterally and the shoulders elevated, making it difficult for optimal visualization and needle placement. **C,** Optimal supine positioning for a cervical procedure. The patient has a small pillow placed to allow the spine to be in a neutral position, allowing all anterior cervical musculature to be relaxed. **D,** Suboptimal positioning of a cervical procedure in a supine position. The patient's anterior cervical musculature is flexed, which makes needle placement challenging.

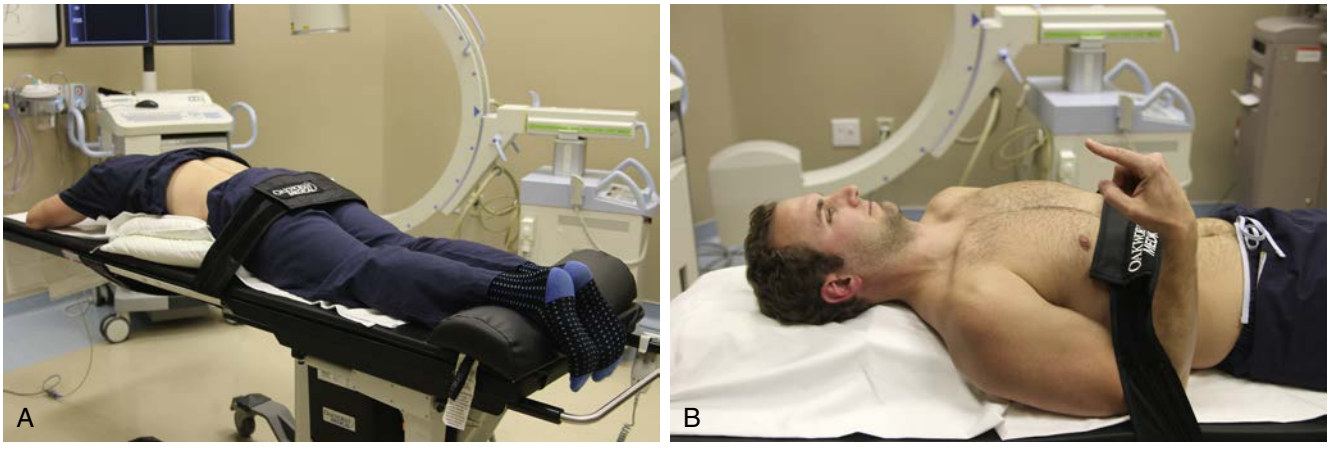

Fig. 5.7. A, Use of strap in a prone patient. This helps to secure the patient. **B,** Use of strap in a supine simulated patient getting a cervical procedure. Note that the simulated patient is unable to move his arm to the procedural site and potentially contaminate the sterile field. Ideally, place the "reminder" strap distal to the elbow.

- A safety "reminder" strap should be used for patients in the prone and supine positions (Fig. 5.7A, B). It aids in maintaining initial patient positioning and provides a gentle "reminder" for the patient to remain still during the procedure and not to contaminate the field. Note that it will be more effective if it is placed distal to the elbow.

MANAGING INFECTION RISK

Steps to Ensure Proper Sterilization

- The performing physician should use sterile gloves and a mask. In certain circumstances, all physicians and staff in the room are required to wear a cap and mask.
- The patient is properly marked.
- The skin prep is performed using a sterile technique. A cleansing or sterilizing agent is used. Care should be exercised to avoid touching nonsterile items (sheets or bedding) with sterile gloves or prep solution sponges.
- The patient is then draped (Fig. 5.8A and B).
- A sterile cover may be used on the image intensifier as indicated (Fig. 5.8C).

Sterilization Agents Used

- Alcohol is an accepted antiseptic agent; however, it should not be used as the sole agent but rather as part of the skin prep regimen. Table 5.1 lists the most commonly used sterilization agents.

Fig. 5.8. A, Drape placed for a lumbar procedure in a prone patient. **B,** Drape placed for a cervical procedure of a supine patient. **C,** Sterile cover placed over the C-arm. This is useful in a procedure on a "thicker" patient and/or one in which a longer needle is used. It is also useful for procedures requiring stricter sterility (spinal cord stimulator trials and discograms).

Table 5.1 The Most Commonly Used Sterilization Agents

Agent	Mechanism of Action	Rapidity of Action	Toxicity
Alcohol	Denatures protein	Most rapid	Drying, volatile
Chlorhexidine	Disrupts cell membrane	Intermediate	Ototoxic, keratitis
Iodine/Iodophors	Oxidation	Intermediate	Skin absorption, skin irritation

Ultrasound-Guided Procedures

- Once a preliminary scan is complete, the patient's skin is first cleansed with a sterile cleanser and then draped as described above.
- A sterile gel and an ultrasound probe cover are applied when preparing for the procedure. Alternatives to a probe cover include sterile gloves or TegaDerm.
- The probe should be cleaned and disinfected between uses.

Tray Setup and Handling of Needles

- Needles should be in the foam stop (Fig. 5.9A) or set up facing away from the performing physician (Fig. 5.9B).
- Needles should not be scattered on the procedure tray or left facing upward in a position where it is more likely for the physician to suffer a needle stick (Fig. 5.9C, D, and E).

Fig. 5.9. A, Optimal tray setup with needles in foam stop. This provides the safest tray environment to prevent a needle stick and/or needle puncture outside of the sterile field. **B,** Optimal tray setup with needles facing away from the performing physician. This is an alternate method for needle placement on the tray that can also decrease the risk of a needle stick. Placing the needle onto the gauze also decreases the chance of piercing through the sterile tray drape, inadvertently contaminating the field. **C,** Suboptimal tray with needles scattered. This setup creates an unsafe environment that places the physician at a higher risk for needle stick by exposing the needle tip. **D,** Picture demonstrating a physician reaching toward the suboptimal tray with needle tips facing up, increasing potential needle-stick risk. **E,** Zoomed in picture demonstrating the suboptimal tray with needle tips facing up, increasing the potential needle-stick risk.

X-Ray Pedal

- Once the procedure is complete, the physician should move the fluoroscopy pedal under the table or to a position where it will not be depressed by patients or staff (Fig. 5.10A).
- Failure to move the X-ray pedal can lead to it being accidentally pushed (Fig. 5.10B), causing increased radiation, as indicated by an overexposed (white) fluoroscopy screen (Fig. 5.10C).

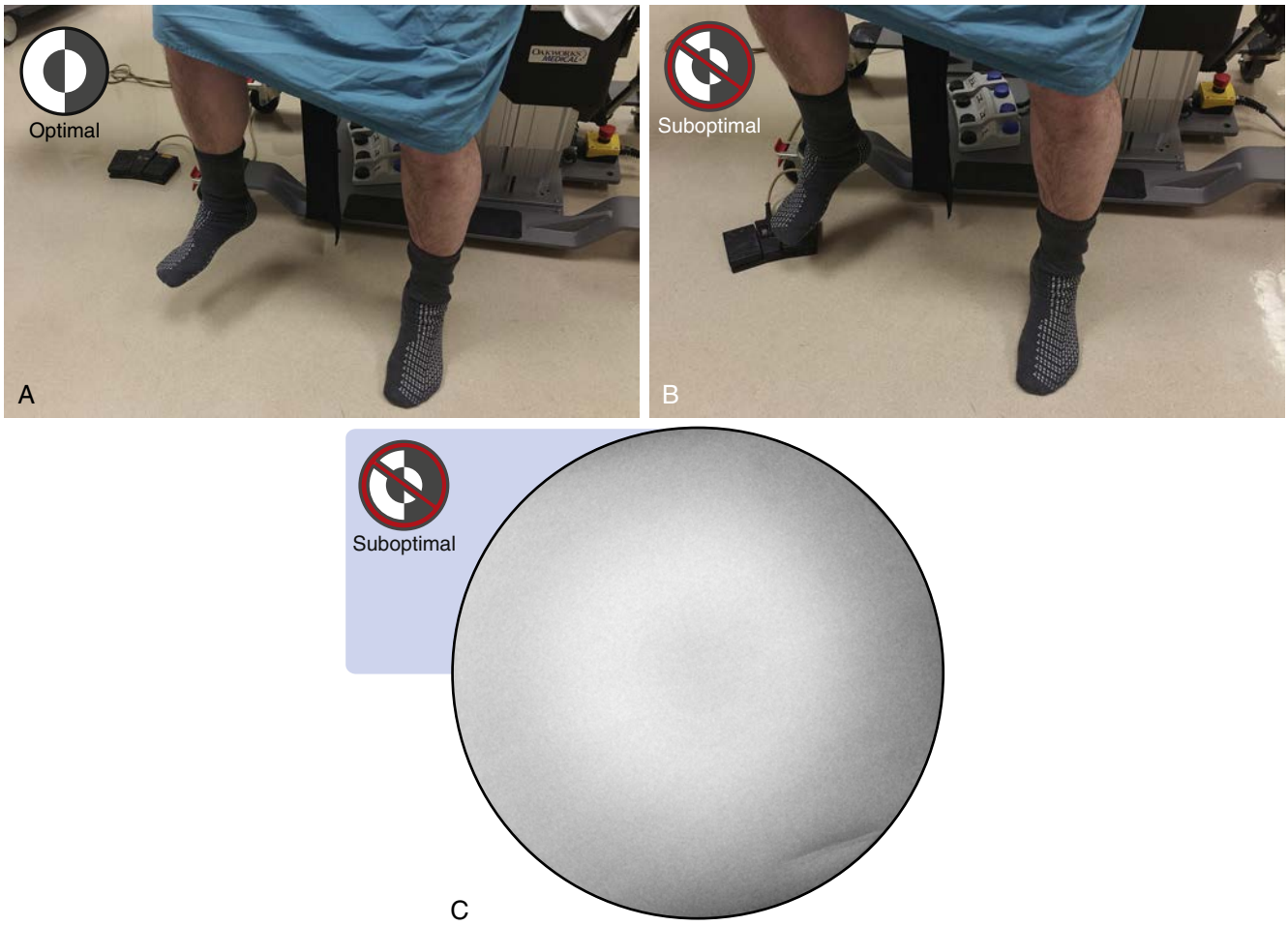

Fig. 5.10. A, Optimal placement of C-arm pedal preprocedure or postprocedure: moved under the table as the patient ascends onto or descends off the table. Note how the pedal is placed under the table so that the patient does not accidentally step on it causing accidental imaging. **B,** Postprocedure placement of suboptimal C-arm pedal, with the patient simulating an inadvertent and unnecessary radiation exposure. **C,** Fluoroscopic image triggered as a result of the patient accidentally stepping onto the pedal.

References

1. http://www.jointcommission.org/assets/1/18/UP_Poster1.PDF.
2. https://www.aaos.org/uploadedFiles/PreProduction/About/Opinion_Statements/advistmt/1043%20Surgical%20Site%20and%20Procedure%20Confirmation.pdf.

Suggested Readings

AIUM Practice Parameter for the Performance of Selected Ultrasound Guided Procedures. American Institute of Ultrasound in Medicine; 2014. http://www.aium.org/resources/guidelines/usguidedprocedures.pdf.

AST Standards of Practice for Skin Prep of the Surgical Patient. Association for Surgical Technologists; 2008. https://www.ast.org/uploadedFiles/Main_Site/Content/About_Us/Standard_Skin_Prep.pdf.

Centers for Disease Control and Prevention. *Guideline for Prevention of Surgical Site Infection, 1999*; 1999.

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CHAPTER 6

Radiation Safety

Kermit W. Fox, Leland Berkwits, and Michael B. Furman

This chapter provides interventionalists practical ways to minimize our patients', our coworkers', and our own radiation exposure. Even one or two seemingly small adjustments in procedure habits can significantly decrease the accumulated radiation exposure received over one's career. This chapter focuses on minimizing radiation exposure by limiting exposure **time,** maximizing **distance** from the source, optimizing use of **shielding,** and performing other useful exposure limiting techniques. We also discuss dosimeter badge result interpretation.

All C-arm positions (antero-posterior, postero-anterior, and lateral) are made with reference to a prone or supine patient. Please see Chapter 3, Table 3.1, for definitions of the different C-arm movements and other conventions used throughout this atlas.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

BACKGROUND

X-rays are not directly detectable by the senses. Comparing X-rays with light gives perspective:

- X-radiation (X-ray) is a form of ionizing electromagnetic radiation that has more energy than visible light and can penetrate solid objects.
- Unlike visible light, X-ray is undetectable by our senses, which can create a false sense of safety.
- There is no lower limit of safe dose of radiation. Any dose of radiation can produce some degree of detrimental effect.
- The effects of X-ray exposure (even high levels of exposure) may not be noticeable until long after exposure.
- Radiation exposure can result in cataract formation, radiation burns, and other permanent changes at the cellular level (e.g., cancer).
- While performing fluoroscopic procedures, the operator should continuously minimize radiation dosage by using all reasonable methods. This principle is referred to as *ALARA* (As Low As Reasonably Achievable) and is a *regulatory requirement* for all radiation safety programs.

This chapter will present a logical and rational approach to fluoroscopic usage, emphasizing *time, distance,* and *shielding* as three major techniques employed to maintain ALARA dosages.

PROPER C-ARM OPERATION: LIMITING EXPOSURE TIME

Limiting fluoroscopic **time** is the most effective way to decrease radiation exposure (i.e., dose). Techniques for doing this will be discussed in this chapter and elsewhere throughout this book.

Operate the C-arm in pulsed mode whenever possible. The total dose delivered to the patient is a result of the X-ray output per unit time and the duration of exposure (dose = dose rate × time). Reduction of radiation exposure dosage can be accomplished by adjusting the mode of operation of the C-arm fluoroscope to reduce the tube X-ray output rate or tube duty cycle (time taken by the tube to operate).

The default mode of fluoroscopic image acquisition is commonly referred to as *continuous* or *conventional* fluoroscopy. In continuous mode, the X-ray tube output is continuously operating for the duration of image acquisition to allow image acquisition to occur at 30 images/second (equivalent to 30 frames/second, which is typically used in cinema). Modern fluoroscopes can be set to obtain images in *pulsed mode*. Pulsed mode operates the X-ray tube intermittently rather than continuously, resulting in a reduced radiation dose. Pulsed mode is typically accomplished in fractions of 30 (e.g., 1/2 mode is 15 images per second, 1/4 mode would be eight images per second). Rates as low as one image per second are typically available on most modern fluoroscopes.

One study found an approximately 50% reduction in fluoro times when switching from automatic exposure settings to pulsed and low-dose mode.[1] However, there is a trade-off in image quality. Higher frame/image rates provide better temporal image quality, at the cost of higher radiation exposure. Typically, a lower pulse rate (4–8 per second) provides adequate temporal resolution.

With experience, the interventionalist will discern when to utilize the various available modes on a given fluoroscope *(e.g., continuous mode fluoroscopy provides increased temporal resolution and therefore may be more appropriate than pulsed mode for contrast visualization under "live" or "real-time" injection).* The interventionalist is encouraged to explore different pulse rates to determine which setting is appropriate for the procedure being performed.

Review available imaging before starting your procedure. Imaging (X-ray, magnetic resonance imaging, computed tomography [CT], etc.) review **uses no radiation.** *Prior* knowledge of the level of a vertebral deformity or spondylolisthesis can serve as a reference point to determine the level at which a procedure will be performed. In comparison, real-time spinal segment counting and other live scans to evaluate levels uses a finite amount of avoidable radiation exposure.

Anticipating the appropriate C-arm position before obtaining an image will limit unnecessary radiation exposure. For example, when setting up a particular trajectory or other view, one can expect that to obtain a "true" anteroposterior view of a segment, the C-arm will need to be tilted appropriately to match the lordosis or kyphosis of the segment of interest (see Fig. 3.1). Likewise, the C-arm will need to be obliqued to the anticipated angle before any exposure occurs. Although in many chapters the need to both tilt and then oblique is emphasized, these motions can of course be combined to further minimize radiation time and exposure. When setting up or changing from one view to another (e.g., anteroposterior to oblique), **properly center the fluoroscope over the targeted structure,** under visual inspection

[1] 1 mSv = 100 mrem.

and/or using the laser, before acquiring the image. When the region of anatomic interest is centered in anteroposterior view and the C-arm is then moved to obtain an oblique view, the visualized structure shifts to the side opposite to which the C-arm is obliqued. Anticipating the need to translate (piston) the C-arm toward the side to which the C-arm is being obliqued can save fluoroscopic exposure time. Also, if an atypical angle is needed to get a "true anteroposterior" (AP), anticipate that the associated lateral image will be at a perpendicular angle.

Use the fluoroscope's laser beam, if available, to line the needle up parallel to the beam (Fig. 6.1). Some C-arms are equipped with a laser pointer that indicates alignment with the center of the image intensifier, which is meant to estimate beam trajectory. One practical use of this laser feature is to assist with the identification of skin entry location and maintenance of parallel trajectory during the needle insertion. After the trajectory view has been established and the target is centered on the fluoroscopic field, the laser can confirm a trajectory parallel to the beam.

While advancing in the trajectory view, the needle should be parallel to the beam (and perpendicular to the flat surface of the image intensifier). If it is not, adjust the needle **before obtaining an image** (Figs. 6.2 and 6.3).

When performing multilevel procedures (e.g., two-level transforaminal epidural steroid injection [TF-ESI] and three-level discogram), place needles at all levels with the use of trajectory view before checking multiplanar imaging. By simultaneously obtaining anteroposterior and lateral images for all needles and repositioning all needles before subsequent images are obtained, radiation exposure can be limited (as compared with checking each level individually).

Most fluoroscopes provide an audible 5-minute timer warning to maintain awareness of total fluoro time.

The Last Image Hold feature digitally "freezes" the last image on the monitor after X-ray exposure is terminated. This allows the operator to study the last image and plan the next move without additional radiation exposure. The authors refer to this as "thinking with your foot off the pedal." A technique preferred by the authors is to **save the last image** and transfer it onto the second monitor prior to adjusting the C-arm to another plane (e.g., transition from AP to lateral). This enables the operator to reference the previous imaging plane to better appreciate the needle location in three-dimensional space (see Chapter 3).

For mid-thoracic interventions, consider using a small gauge "marker" needle (e.g., 25 gauge) to provide a visual reference at the level to be injected. This will prevent the need for repeat localation of the level after repositioning the C-arm. See Chapter 20 (Thoracic Interlaminar ESI) for an example of marker needle use.

Fig. 6.1. The fluoroscope's laser beam can be used to center over a target, identify the skin-entry location, and maintain a parallel trajectory during the needle insertion.

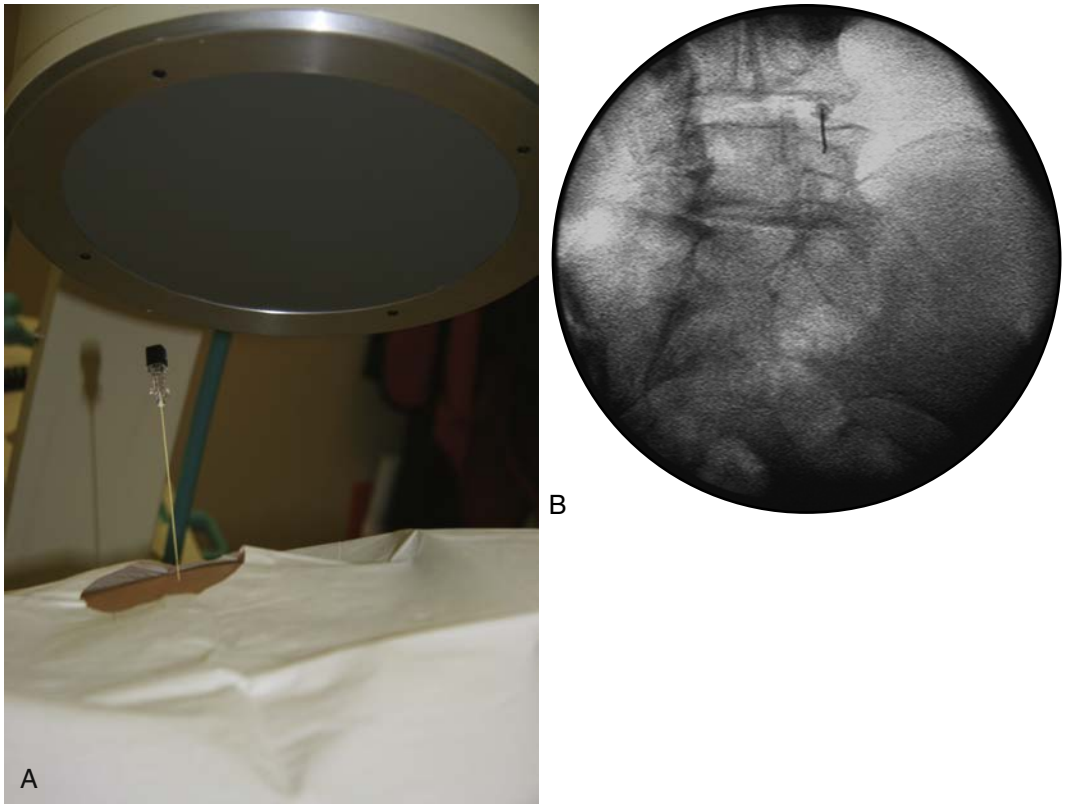

Fig. 6.2. A, For this right-sided L5 transforaminal epidural steroid injection, the needle has been inserted in a direction not parallel with the beam. Notice the needle position relative to the image intensifier. **B,** The unnecessary fluoroscopic image only confirms what was obvious in part A of this figure; corrections should have been made before the fluoroscopic image was taken.

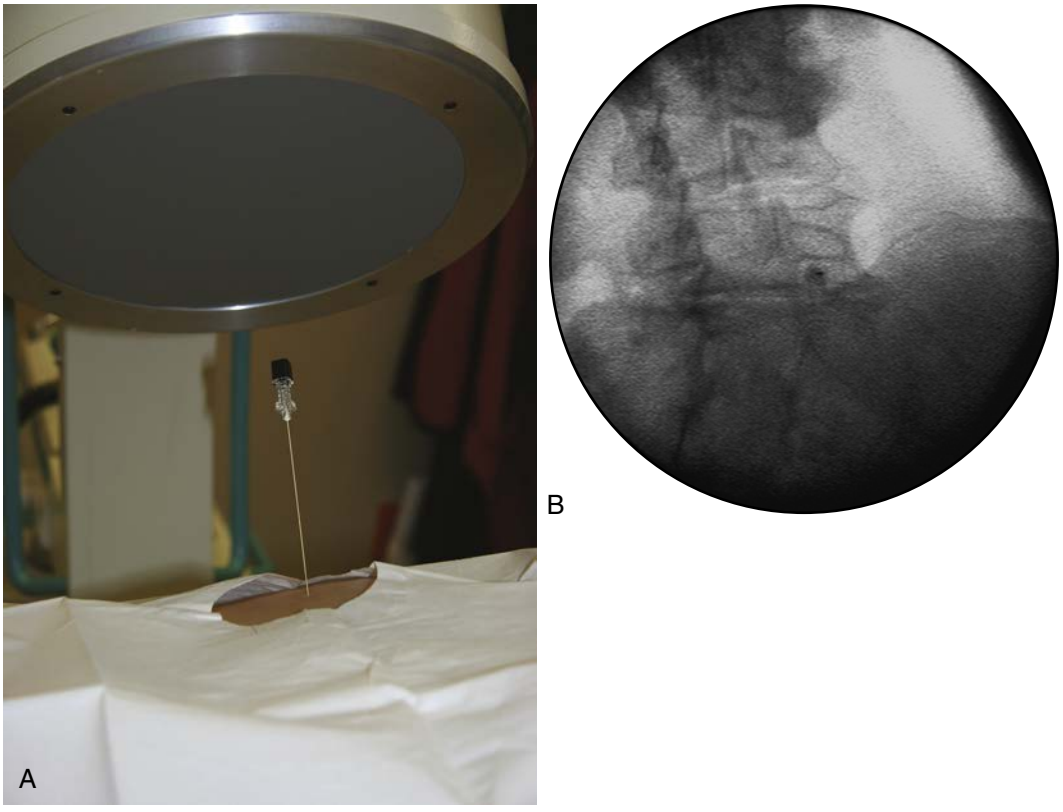

Fig. 6.3. A, The needle has now been adjusted and appears to be inserted parallel to the beam. **B,** The fluoroscopic image confirms an exposure parallel to the needle, with the hub and needle in line (i.e., a "hubogram"; see Chapter 3).

PROPER C-ARM OPERATION: MAXIMIZING DISTANCE

Maintaining maximal operator distance from the X-ray source throughout the procedure is an important way in which accumulated radiation exposure can be minimized. This is based on the **inverse square law** (Figs. 6.4 to 6.10). The major source of occupational radiation exposure to the operator is scatter radiation from the patient. The greatest scatter radiation received by the operator is during the lateral view. The operator should be educated to not only maximize his or her distance from the X-ray source but also maintain distance from the patient during image acquisition.

While magnification of an image provides better visualization, the inverse square law dictates that this comes at the cost of increased radiation exposure to the patient and increased scatter exposure to the operator. Every effort should be made to maintain patient distance from the source (Figs. 6.12 to 6.13).

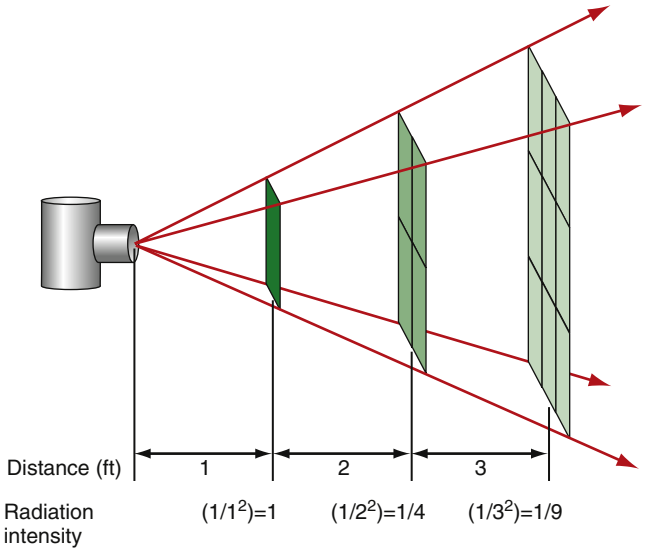

Fig. 6.4. The inverse square law. As the distance from the source increases, radiation intensity decreases exponentially.

Fig. 6.5. This experienced interventionalist has stepped away from his patient and X-ray source prior to the fluoroscopic acquisition. The red portions of this and subsequent figures simulate the direct fluoroscopic beam, and the yellow portions simulate the scatter. Our simulation does not properly depict the true *extent or* volume of the X-ray absorption by the patient or the true amount and direction of the scatter.

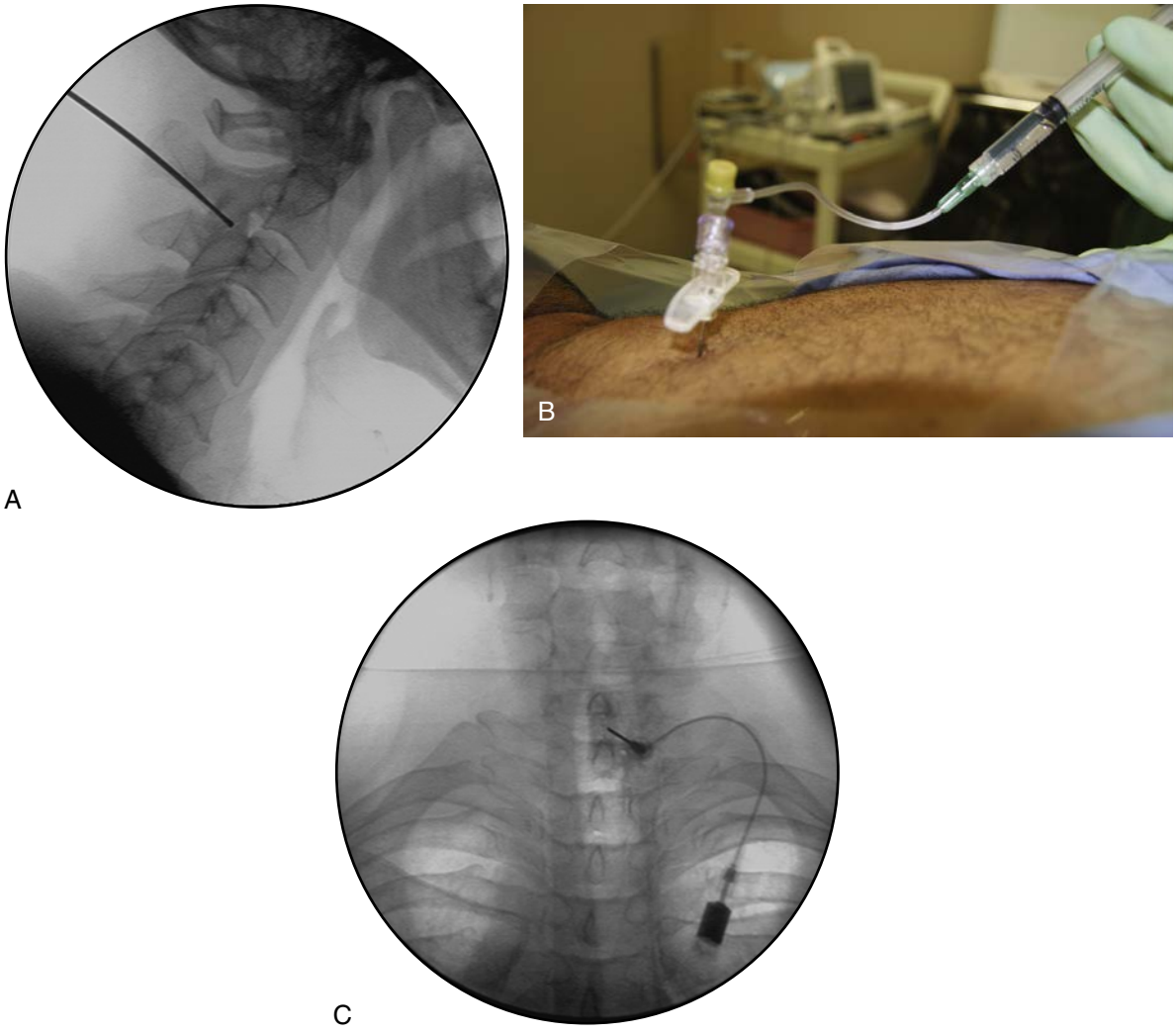

Fig. 6.6. During skin marking and target localization with live fluoroscopy and live contrast injection, the interventionalist can still minimize the exposure by using longer metallic markers (**A**) and extension tubing (**B** and **C**) to keep his or her hands out of the field. For almost all static images, the radiation exposure can be even further minimized by maximizing one's distance from the source during exposures. One caution is that metallic markers, particularly thick markers (e.g., sponge sticks), may inadvertently increase overall patient radiation exposure as the fluoroscope attempts (on automatic exposure settings) to penetrate the marker by increasing the kV output. It is recommended that the interventionalist check his or her individual fluoroscope to see if this occurs during setup for procedures.

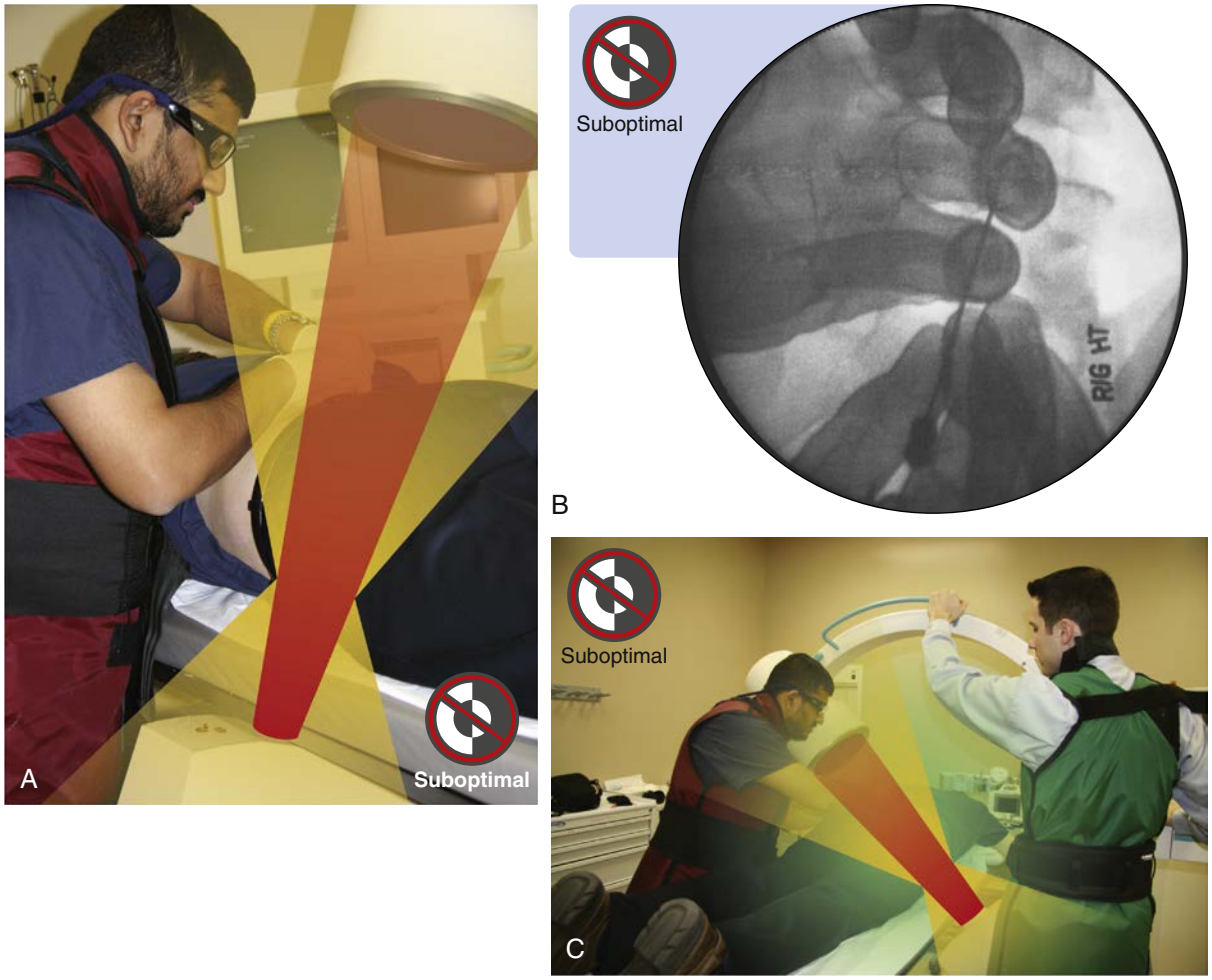

Fig. 6.7. A, This less-experienced interventionalist is seen leaning up against the X-ray source as he prepares to take a fluoroscopic image. **B,** He has also taken an exposure of his hands. **C,** When the C-arm is operating at oblique angles, the X-ray source may be positioned closer to the interventionist (not shown) or to the C-arm operator or technician (shown).

Fig. 6.8. This experienced interventionalist is positioned to keep maximal distance between himself and the patient. He has instructed his operator to lock the C-arm and step away from the X-ray source before the picture is taken.

Fig. 6.9. This experienced interventionalist is careful to step away from the patient and stand behind the X-ray source before any pictures are taken. This position is optimal for avoiding scatter while taking a lateral image. (Compare to Fig. 6.10.)

Fig. 6.10. When working with lateral imaging, the proximity of the X-ray source is often not appreciated. Compare the interventionalist's position to that in Fig. 6.9. The simulated fluoro beam and scatter illustrate that the interventionalist will get higher radiation exposure if he stays close to the X-ray source while taking a lateral picture.

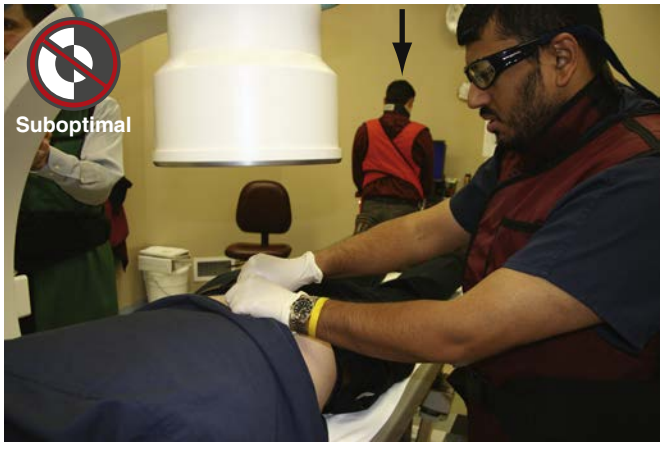

Fig. 6.11. This less-experienced interventionalist is intently focusing on his procedure and is unaware of his teammate's position. Notice that his teammate (black arrow) is wearing an open-backed lead apron. Although it is lighter than a wraparound apron, it does not offer any protection to most vital organs when the wearer's back is turned toward the X-ray sources. Except for his lead apron straps, he is totally exposed to the radiation source. Some radiation may actually be reflected back from the front of the apron.

Fig. 6.12. Keeping the image intensifier further from the patient allows for a more magnified image. An X-ray tube in close proximity to the patient exposes the patient to an unnecessarily high intensity of radiation and exposes the operator to increased scatter. For this reason, many fluoroscopy units come with a spacer to limit the proximity to which the tube can approach the patient.

Fig. 6.13. This experienced interventionalist has asked his assistant to lower the C-arm source or raise the table, thus placing distance between the patient and the X-ray tube. Notice that he has still left himself sufficient workspace between the patient and the image intensifier.

PROPER C-ARM OPERATION: SHIELDING

Collimation is a form of shielding that operates at the X-ray source. Collimation reduces the X-ray source aperture using a remotely controlled lead shield within the housing of the X-ray tube, resulting in reduced exposure to the patient and operator. Typical collimation functions include circular collimation, sometimes referred to as "iris" or "cone" collimation, and linear collimation, referred to as "leaf" collimation. By collimating the X-ray source to include structures of similar density, the image quality can be improved and exposure of the patient and operator can be reduced (this is discussed in Chapter 3, Figs. 3-33 and 3-34).

As a final line of defense, appropriate attire and shielding provide **protection,** thus limiting the exposure of sensitive tissues to any remaining radiation (Figs. 6.14 to 6.16). A table "skirt" shield can also be used to reduce the exposure of the operator's lower body against back-scattered radiation. Shielding the patient can also reduce exposure. This is accomplished by using shielding material over which the patient is placed so that the shield is located *between the X-ray source and the patient,* thereby blocking patient direct exposure and reducing operator scatter exposure. For patients of childbearing age, carefully placed gonadal shielding is appropriate if the placement does not significantly block the field of procedural visualization. If a shield is on the edge of the visualized field, causing the C-arm auto-exposure to overexpose the field of interest, collimation may be helpful in excluding the shielded region from the visualized field and improving the image quality. Studies have shown that the use of multiple shielding methods can reduce radiation exposure by as much as 98.7%.

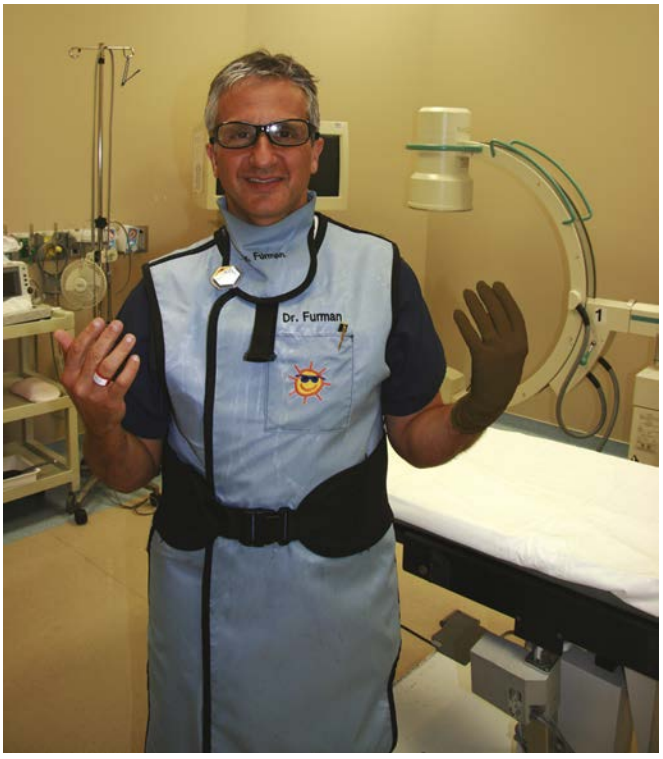

Fig. 6.14. Appropriate attire includes a lead apron, a thyroid shield, shielded glasses, and lead-lined gloves (optional). Dosimeter badges and rings are useful for monitoring accumulated radiation exposure. The dosimeter badge is placed in a prominent location, typically near the chest, and it should be centered or facing toward the side that is in closer proximity to the beam. Similarly, the ring is placed on the hand that is in closer proximity to the beam. In this picture, the ring has been rotated for better visualization. The recording surface should face the X-ray source, typically the palmar surface of the hand.

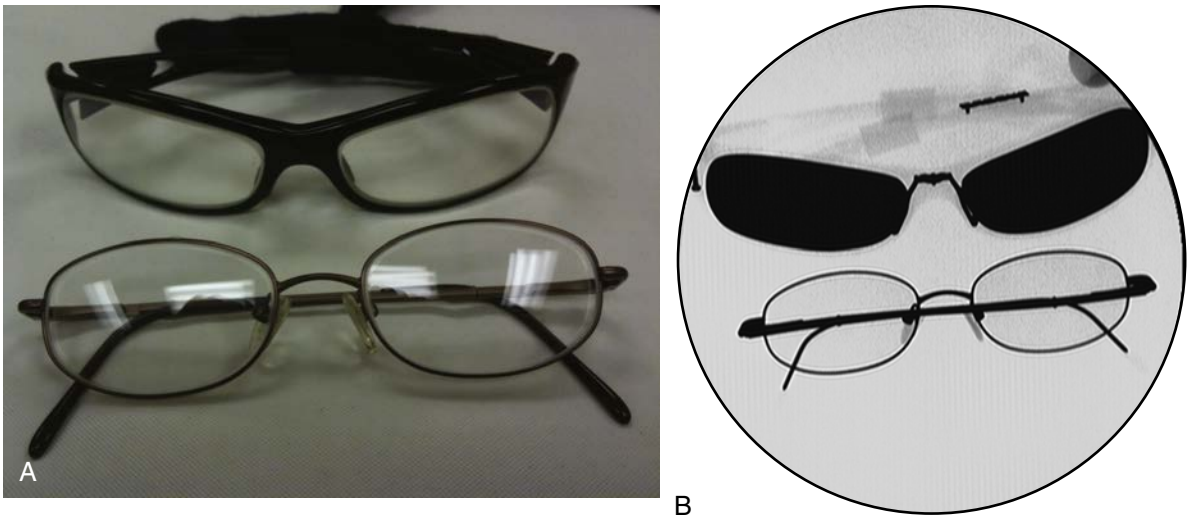

Fig. 6.15. A, To the naked eye, there is little difference between lead-impregnated or "shielded" glasses (top) and commercial eyeglasses (bottom). **B,** When these same glasses are placed under a fluoroscopic beam, the benefits of shielding become obvious. The lead-impregnated lenses of the shielded glasses appear opaque, which suggests a nearly complete attenuation of the X-radiation. The commercial lenses are virtually the same shade as the background, which demonstrates that they allow nearly 100% of the radiation to pass through without attenuation. The eyes have a relatively low threshold of recommended radiation exposure. The theoretical risk of cataract formation (see Table 6.1) dictates that proper radiation protective eyewear must be worn.

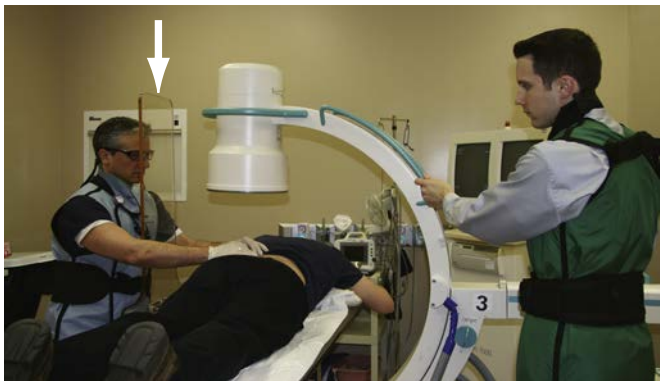

Fig. 6.16. Translucent radiation shield (white arrow) provides additional protection from scatter. Even with shielding, the physician's hands are still exposed, requiring the physician to be mindful to move his hands out of the field prior to obtaining any images.

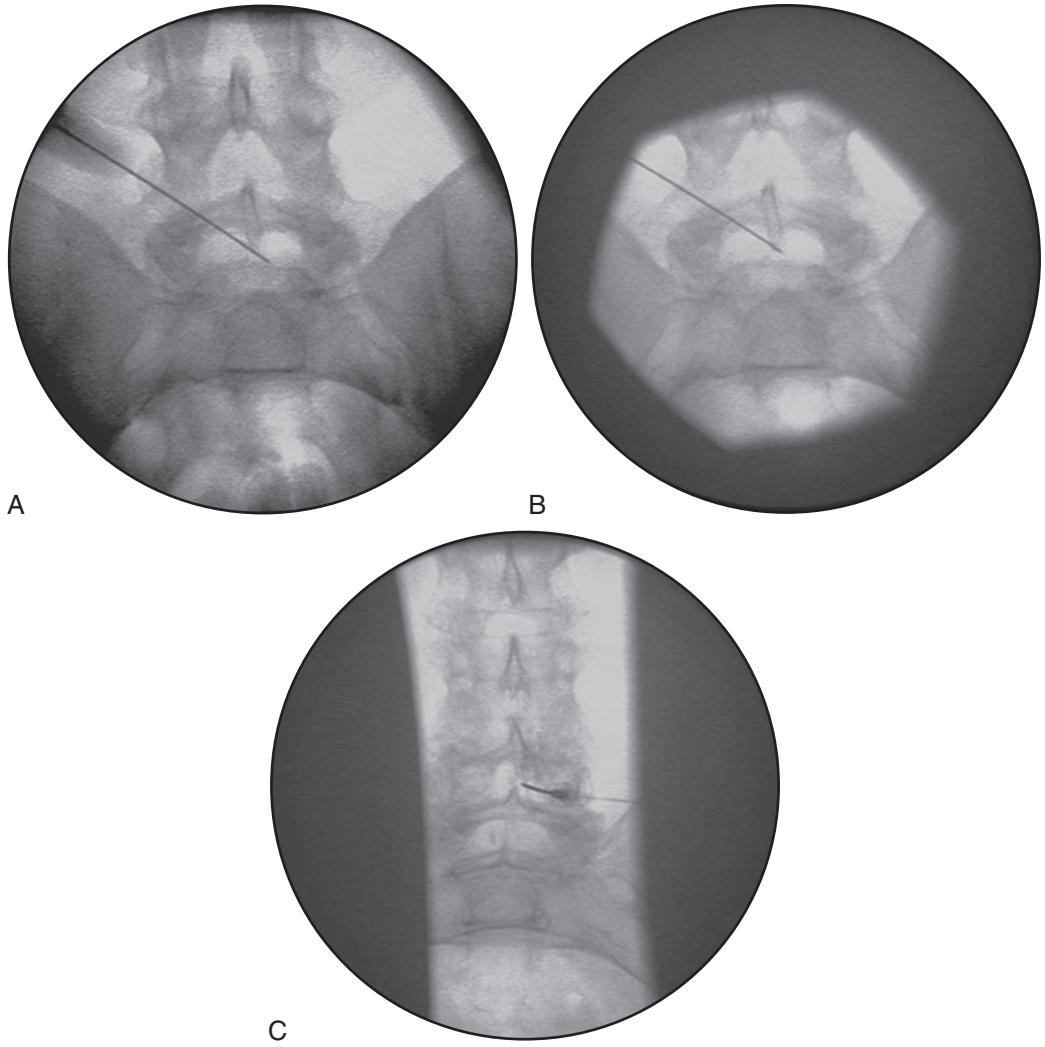

Fig. 6.17. A, Part of the interventionalist's hand is shown in the field holding a metallic marker. By using either **B,** iris collimation or **C,** side-to-side collimation, the interventionalist can limit radiation exposure by keeping his or her hands out of the beam while injecting contrast under live fluoroscopy. Note the use of extension tubing in part **C** of this image, which also keeps the interventionalist's hands out of the beam.

OTHER USEFUL TECHNIQUES TO LIMIT RADIATION EXPOSURE

Use Low Dose Mode whenever possible. Many conventional fluoroscopes are capable of operation in various dose modes, commonly referred to as "low dose," "medium dose," and "high dose." As the names imply, each mode allows a different output of X-ray radiation per unit time, with low-dose mode generating the least amount of X-radiation per unit time.

Use strategies that work with or compensate for the fluoroscope's automatic exposure setting. A fluoroscope defaults to an automatic exposure adjustment. When the fluoroscope encounters large variations in tissue densities (e.g., lung fields in the thoracic spine and shoulders in the cervical spine), it incorrectly adjusts its radiation output, thereby potentially resulting in poor image quality and fluctuations in radiation exposure. These techniques are also discussed in Chapter 3 because they often optimize image quality as well.

The following strategies are used to adjust or compensate for automatic exposure:

- **Adjust the fluoroscope position and collimate the image** so that only structures of similar densities are visible in the field.
- **Disable the automatic exposure and manually adjust the exposure** so that the structure of interest is properly exposed. This is only recommended when other strategies have not helped with exposure (see Chapter 3).

RADIATION EXPOSURE MONITORING

Monitoring Interventionalists and Staff Radiation Exposure

In addition to performing the previously mentioned actions to minimize radiation exposure, interventional physicians and staff should wear their radiation dosimetry badges and rings. These are common devices that are used to monitor accumulated radiation exposure (see Fig. 6.14). When badge and ring dosimeters are provided to a facility, a "control" dosimeter is also provided to monitor background radiation. The control dosimeter should be placed in an area that is not adjacent to the radiation-producing equipment. This may also be considered as a safe place to store all badges when they are not in use. Radiation badges are typically worn outside the lead protection on the thorax or neck by all individuals who work within the fluoroscopy suite. Pregnant women can also wear fetal badges under their lead protective gear to monitor potential fetal exposure. *The badge comprises different regions of filtration that estimate tissue exposures at various depths. Deep-tissue exposure ("D" in the sample report* [Fig. 6.18]*) estimates exposure to the major organs. The eye and shallow-tissue measurements ("E" and "S," respectively, in the sample report* [Fig. 6.18]*) estimate lens and skin exposure, respectively.*

Interventionalists also often wear dosimetry rings. Because the digits do not contain deep-tissue organs, the rings estimate only the shallow-tissue exposure.

"Assigned" is the calculation of estimated deep-tissue exposure that takes into account the lead apron worn by the interventionalist. The assumption that appropriate attire is worn (see Fig. 6.14) gives a more accurate estimation of deep-tissue organ exposure. It is usually calculated using the formula given on the back of the monthly dosimetry report. The assigned value is usually listed immediately below the collar or badge measurements, and it is the value that is used for year-to-date and lifetime deep-tissue measurements. Because peripheral skin is considered to be exposed to radiation, it does not have an assigned value calculated. Although many interventionalists wear lead-impregnated lenses (see Fig. 6.15), the eyes are considered to be exposed; hence, they also do not have an assigned value calculated.

Background and incidental environmental exposures are listed as controls. When they are minimal, they are usually labeled in reports as "M." This is based on the control badge and assigned value. Badges and ring dosimeters should never be worn outside the procedural/clinical area as they are heat, moisture, and chemical sensitive. When not being worn, dosimeters should be stored in a dry, room-temperature environment, away from potential radiation sources.

Dosimeters are typically replaced on a monthly basis. To ensure that exposure levels do not exceed the established safety thresholds (Table 6.1), monthly reports are generated for review. For deep tissue, the assigned value is typically used to determine if the individual has exceeded exposure limits. *Should an interventionalist exceed quarterly or annual thresholds, he or she will be required to limit (or possibly even cancel) his or her procedure time until his or her exposure levels are appropriate.* When interpreting the report, one must consider time spent in procedures (which is not usually listed on reports), trends in readings over time, and any disparities among monitoring devices (i.e., dosimeters). Tracking trends in exposure over time provides an interventionalist with the feedback regarding how changes in the technique minimize the radiation exposure (Fig. 6.18 and Box 6.1).

Table 6.1 Annual Radiation Exposure Limits*

Whole body, blood-forming organs, and gonads (i.e., deep tissue):	5000 mrem/yr
Lens of the eye and thyroid (i.e., eye): Radiation-induced lens opacities Radiation-induced cataracts	15,000 mrem/yr Acute dose > 1000 mrem Acute dose > 5000 mrem
Chronic dose threshold unknown	-
Extremities and skin (i.e., shallow tissue)	50,000 mrem/yr
Fetal	500 mrem/gestation period
General public (i.e., incidental environmental/background exposure)	100 mrem/yr
Cumulative dosage (lifetime)	1000 mrem × Age in years

*Based on United States Nuclear Regulatory Commission Regulations, Title 10, Part 20, Code of Federal Regulations, which has been adopted by many states. Certain states and other regulatory agencies may adhere to different limits.

Note that these values (with the exception of acute lens opacity) are determined with the assumption of consistent exposure. The value for *intensity* of exposure is as important as *cumulative* exposure. For example, an interventionalist who is exposed to more than half of the recommended annual dosage in 6 months would be considered to have exceeded the recommended limits. The same principle can be applied to monthly, weekly, or even daily exposure.

Finally, given the relatively infrequent patient exposure to radiation, long-term dose/accumulated exposure is not considered a significant concern. The incidence of excessive radiation exposure is reported, and it is observed that nearly all the potential acute exposure effects are skin-related (Table 6.2).

Name	ID	Sex	Use	Dose Equivalent (mrem)									
				July 2010			YTD			Lifetime			Incpt
				D	E	S	D	E	S	D	E	S	
Zoff, Han M.D.	1234	M	Collar	75	125	125	450	925	900	8750	18500	17700	9-00
			Ring			120			850			16500	
			Assigned	23			140			2630			
Newhear, Eym M.D.	9999	M	Collar	350	675	685	8800	10500	10300	8800	10500	10300	1-10
			Ring			717			11100			11100	
			Assigned	105			2640			2640			
Tyme, Par M.D.	1225	F	Collar	150	185	200	850	1350	1400	3400	5100	5450	7-08
			Ring			NR*			NR*			NR*	
			Assigned	45			255			1050			
Control			Collar	M	M	M	6	12	12	120	200	210	9-00

*NR = Not Reportable

Fig. 6.18. A sample monthly radiation dosimetry report (1 Gy = 100 Rad = 100 Rem).

Box 6.1 Interpretation of Radiation Dosimetry Report

1. Dr. Han Zoff, an experienced physician, has consistent levels of radiation exposure. His monthly exposure level (i.e., reading) matches his year-to-date (7 months) reading (green circles). His ring reading is similar to his shallow-tissue (i.e., collar/badge) reading, which implies that he keeps his hands at an appropriate distance from the beam.
2. Dr. Eym Newhear, a less-experienced physician, has a lower reading in July than predicted by his year-to-date reading. This could be the result of less procedure room time, or he may be maintaining a more appropriate distance from the beam. His ring reading is higher than his collar/badge reading (blue circles), which suggests that his hands are too close to the beam. His year-to-date deep-tissue exposure is very high, with the assigned value approaching the exposure limit, and his eye exposure is also approaching the exposure limit. His mid-year reading is already past 50% of the annual limit. He may be required to decrease his procedure room time.
3. Dr. Par Tyme works only half time. As a result, she has a relatively low reading in July. Her distance relative to the beam cannot be estimated, because her ring information is not available (orange circle).

Table 6.2 Potential Effects of Fluoroscopy on Skin

Effect	Single Dose (mrem)	Onset	Peak
Early transient erythema	200,000	Hours	≈24 hours
Erythema	600,000	10 days	≈2 weeks
Dry desquamation	1,000,000	≈4 weeks	≈5 weeks
Dermal atrophy	1,000,000	>14 weeks	—
Dermal necrosis	1,800,000	>10 weeks	—
Secondary ulceration	2,000,000	>6 weeks	—
Skin cancer	Unknown		

Monitoring Patient Radiation Exposure

Fluoroscopic procedure time or "fluoro time" has traditionally been used to estimate a patient's procedural radiation exposure. Fluoro time alone does not account for variations in beam intensity or beam collimation, which reduces radiation exposure. For example, if two patients are undergoing the same procedure and they ultimately require the same fluoro time, one might expect that they will have similar radiation exposures. If one of the patients, however, is morbidly obese, he or she may require extensive use of high-level fluoroscopy (i.e., "boost" exposure) to obtain an appropriate image quality. Although both patients will experience similar fluoro exposure times because of the higher X-ray tube output rate, the obese patient will experience a greater total dose of exposure. It is therefore important for the reader to appreciate that the duration of exposure cannot be used to measure or compare the total radiation dosage to which the patient is exposed.

Because exposure time does not truly represent the amount of ionizing radiation received by the patient, other more accurate methods of estimating the dose received by the patient have been developed. These include the Kinetic Energy Released per Mass of Air (KERMA) and the Dose Area Product (DAP).

Radiation dosimeter reports commonly list exposure in millirem (mrem) (see Fig. 6.18). As Gray (Gy) is the International System of Units (SI) standard for absorbed radiation dose, the interventionalist is encouraged to be familiar with both units and their conversion (see Fig. 6.18 caption). KERMA is a measurement of radiation concentration at a given point in space; therefore, it takes into account changes in the beam's energy (e.g., variations in kV and mA). Practically speaking, KERMA measures the ionizing radiation energy (joules) released per unit mass (kg) in a given space of air, and it is expressed in the units of joules/kg (J/kg); this is equivalent to the unit that is used for representing the absorbed dose, which is known as *Gray.* Although fluoroscopes do not include actual ionization chambers to directly measure KERMA, modern fluoroscopes often include software that can be used to estimate this measurement.

DAP, represented in rad/cm^2, incorporates the area of opening of the beam collimator, and it represents an estimation of patient exposure. DAP takes into account the usage of high-level fluoroscopy when estimating patient exposure; this has been incorporated into many newer fluoroscope units.

It is important to understand that both DAP and KERMA do not take into account the distance of the source from the patient. In addition, they do not quantify radiation exposure to individual tissues (e.g., bone, fat, muscle). Further discussion about this topic is beyond the scope of this atlas. Please see the list of Suggested Readings for additional information.

Quantifying Patient Radiation Exposure: A "Real-World" Perspective

A frequent concern expressed by the interventionalists is "I read all of these articles about mrem, Gy, and tissue exposure, but my patients (and many of my non-interventional physician colleagues) don't understand these terms. When they ask me how much radiation they will receive with their procedure, I don't know what to tell them. How can I quantify potential exposure in terms that my patients will understand?"

Let's assume the procedure is a two-level (or bilateral) lumbar TFESI with a 40-second fluoro time.

- A 40-second lumbar TFESI has approximately 0.93 milliSieverts (mSv) exposure
- A chest X-ray has approximately 0.1 mSv exposure
- A chest CT has approximately 8 mSv exposure

A typical two-level lumbar TFESI has approximately the same radiation exposure as ten chest X-rays or one-tenth of a chest CT (i.e., one hundred chest X-rays equal one chest CT).

Although this explanation is sufficient for health care professionals, a few helpful analogies are provided below for discussion with patients:

A two-level (or bilateral) lumbar TFESI with a 40-second fluoro time has radiation exposure equivalent to the following examples:

- Flying in a jet plane at 38,000 feet (typical cross-country altitude) for 3 hours (approximately 0.3 mSv/hr)
- Driving 400 miles in a car
- Normal background radiation exposure over a 3-month period (approximately 0.01 mSv/day or 1 mrem/day)

Suggested Readings

Brateman L. Radiation safety considerations for diagnostic radiology personnel. *Radiographics*. 1999;19(4):1037–1055.

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CHAPTER 7

Caudal Epidural Steroid Injection

The caudal epidural steroid injection is one of the oldest interventional techniques used to treat lumbar and sacral spinal pain. Caudal epidural injections are indicated for radicular symptoms with or without axial pain as a result of a lumbosacral cause. A caudal approach may be a better way to access the epidural space in patients who have undergone a previous surgery on the lumbar spine and/or who have a difficult anatomy limiting transforaminal access to the target levels.

The procedure is not selective; volumes as high as 10 cc have been used to reach more superior lumbar structures. Of course, larger volumes necessitate less concentrated injectate and can be quite uncomfortable. The injectate volume may be determined after observing contrast flow relative to target structures. Occasionally, a catheter can be used to achieve specific epidural flow to a particular location (e.g., beyond surgical scarring or spondylosis), with lower and more concentrated injectate volumes.

We will describe three techniques:

- Caudal epidural steroid injection, shallow angle approach.
- Caudal epidural steroid injection, steep angle approach.
- Caudal epidural steroid injection, ultrasound-guided approach.

With both the shallow and steep angle approaches described in these chapters, the AP view is used to maintain the needle midline. The lateral view is used to access the sacral hiatus and to avoid going ventrally into the viscera or too shallow dorsally.

Reference

1. Sekiguchi M, Yabuki S, Satoh K, Kikuchi S. An anatomic study of the sacral hiatus: a basis for successful caudal epidural block. *Clin J Pain*. 2004;20:51–54.

Suggested Readings

Aggarwal A, Aggarwal A, Harjeet, Sahni D. Morphometry of sacral hiatus and its clinical relevance in caudal epidural block. *Surg Radiol Anat*. 2009;31(10):793–800.

Black MG. Anatomic reasons for caudal anesthesia failure. *Anesth Analg (Cleve)*. 1949;28(1):33–39.

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Willis R. Caudal epidural blockade. In: Cousins MJ, Bridenbaugh PO, eds. *Neural Blockade in Clinical Anesthesia and Management of Pain*. 2nd ed. Lippincott; 1988:361–383.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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CHAPTER 7A

Caudal Epidural Steroid Injection—Shallow Angle Approach: Fluoroscopic Guidance

Justin J. Petrolla and Michael B. Furman

Unlike most other fluoroscopic techniques described in this atlas, there is no specific trajectory. The palpation of the sacral hiatus in combination with imaging is required to determine the proper insertion site. This technique allows driving a needle more superiorly; therefore, it may also be used to introduce a catheter through a larger bore catheter. Both anteroposterior (AP) and lateral views are utilized to avoid advancing the needle tip too far cephalad beyond the S3 level.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 7A.1)

No trajectory view is available for this technique.

PALPATION

The physician must palpate the sacral hiatus with a gloved hand because this is the entry point for the spinal needle. Although the sacral hiatus can be fluoroscopically visualized (not shown), we recommend palpatory confirmation. The sacral cornu and sacral hiatus may not be palpable in obese patients. In such cases, the use of a hemostat to tent the skin in the midline during lateral fluoroscopy (or ultrasound use) may help define the starting point and trajectory.

Notes on Initial Needle Entry

- Note the angle of the needle that is required to enter the sacral hiatus.
- Care must be taken so that the needle correctly enters the sacral hiatus.
- The needle will need to be at an angle of at least 45 degrees or shallower to correctly enter the sacral canal.
- If the angle is too steep, the needle may potentially pass through the sacrum.
- Too steep of an entry angle is a common mistake when first performing this injection.

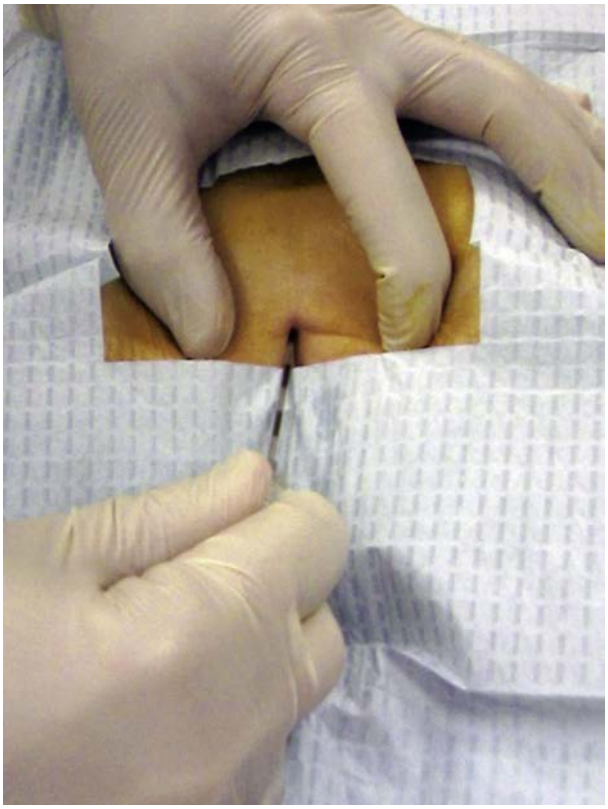

Fig. 7A.1. After palpating the sacral hiatus, a needle is placed so it enters the hiatus with a shallow angle.

Optimal Needle Position in Multiplanar Imaging (Fig. 7A.2)

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW

A lateral view is obtained to visualize the needle angle relative to the sacral hiatus and sacrococcygeal periosteum. The use of collimation in the lateral view helps better define the image.

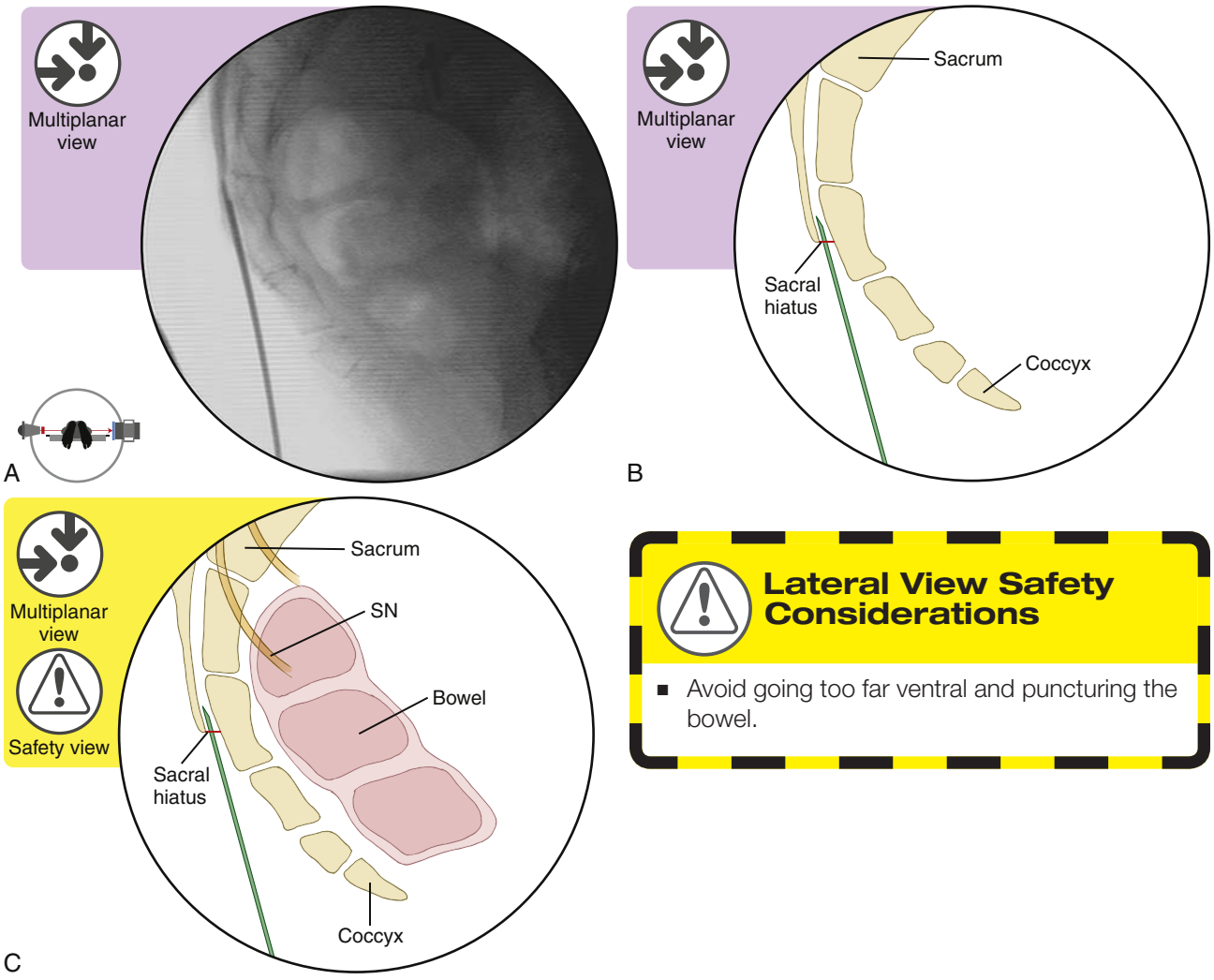

Fig. 7A.2. A, Fluoroscopic image of a lateral view with the needle in position at the sacral hiatus. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 7A.3)

After the needle is confirmed to be in the epidural space in the lateral view, reposition the C-arm back to a "true" AP view. The needle may be advanced in the midline or directed toward the patient's more symptomatic side. The needle tip should be ideally placed no higher than the S3 level to avoid dural sac contact or puncture.

Comments for Anteroposterior Imaging

- Stay close to the midline to stay within the epidural space.
- The needle tip can be directed toward the more symptomatic side.

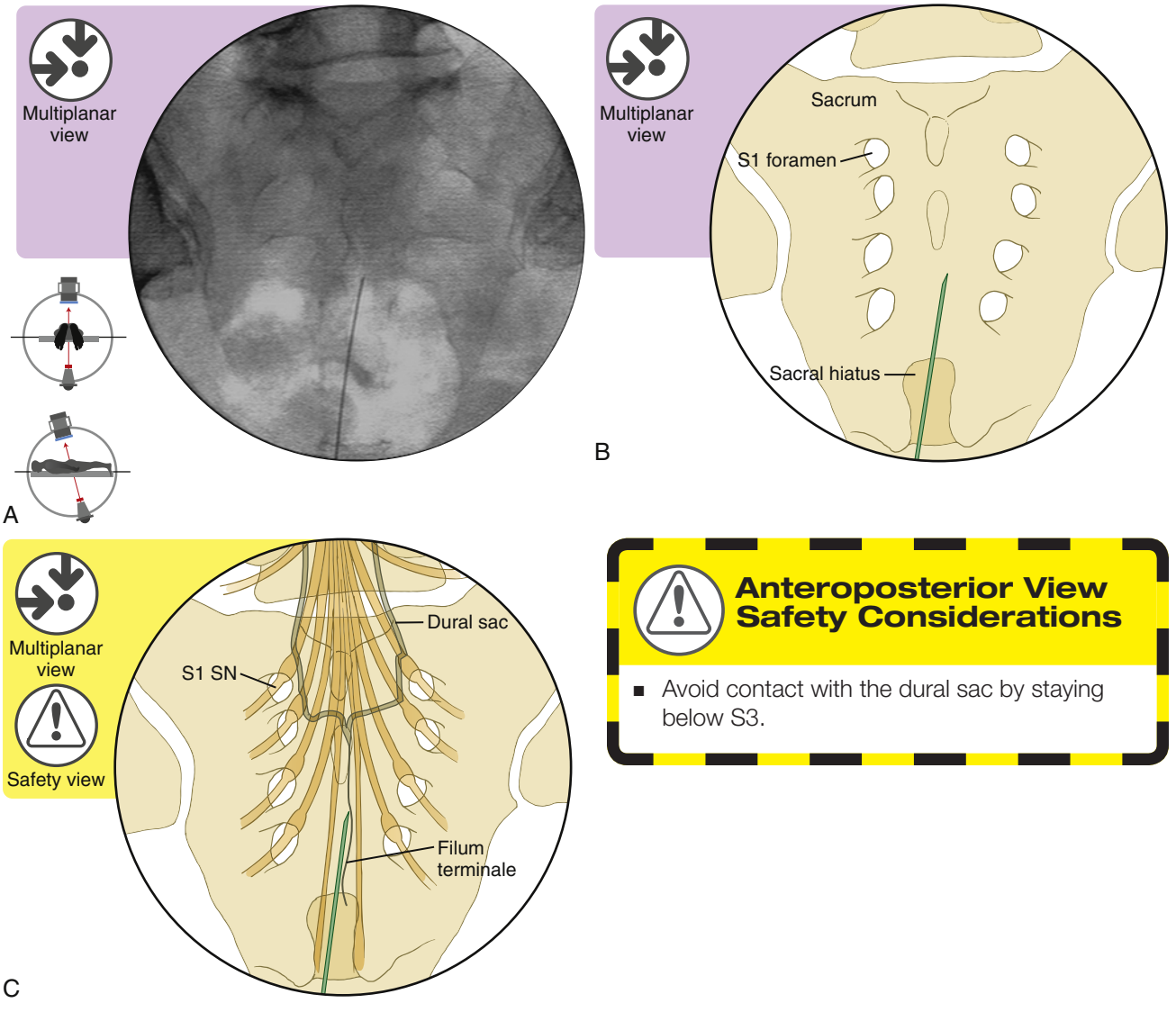

Fig. 7A.3. A, Fluoroscopic anteroposterior view with ideal needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

Optimal Image (Fig. 7A.4)

- Contrast flow should be more localized to the symptomatic side.
- Epidural fat gives an irregular appearance.
- The contrast should spread cephalad and caudad for two or more levels. However, this may be limited in cases of central stenosis or scarring secondary to prior surgery.

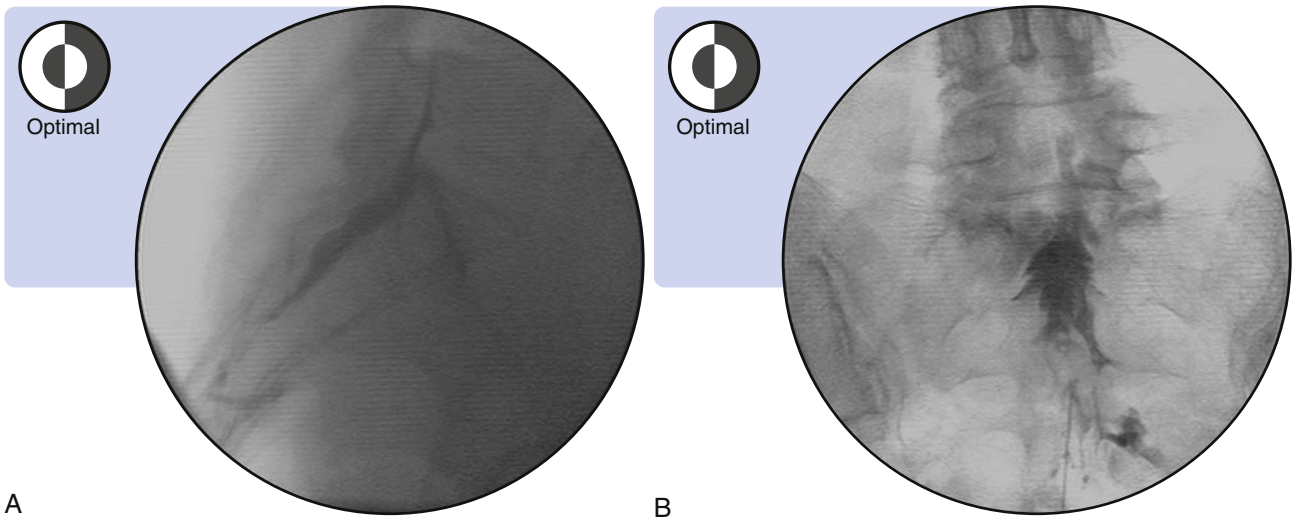

Fig. 7A.4. A, Lateral fluoroscopic image of a lumbar caudal epidural steroid injection of 3.0 cc. **B,** Anteroposterior fluoroscopic image of a caudal epidural steroid injection of 3.0 cc of contrast.

CAUDAL EPIDURAL STEROID INJECTION WITH A CATHETER (FIGS. 7A.5 AND 7A.6)

Occasionally, a catheter is required to reach areas that are cephalad to scarring, a surgical site, or significant spondylosis and associated central and/or foraminal stenosis. The catheter must be "floated" or advanced past the surgical or spondylotic site. Adhesions, stenosis, or hardware may make advancement difficult.

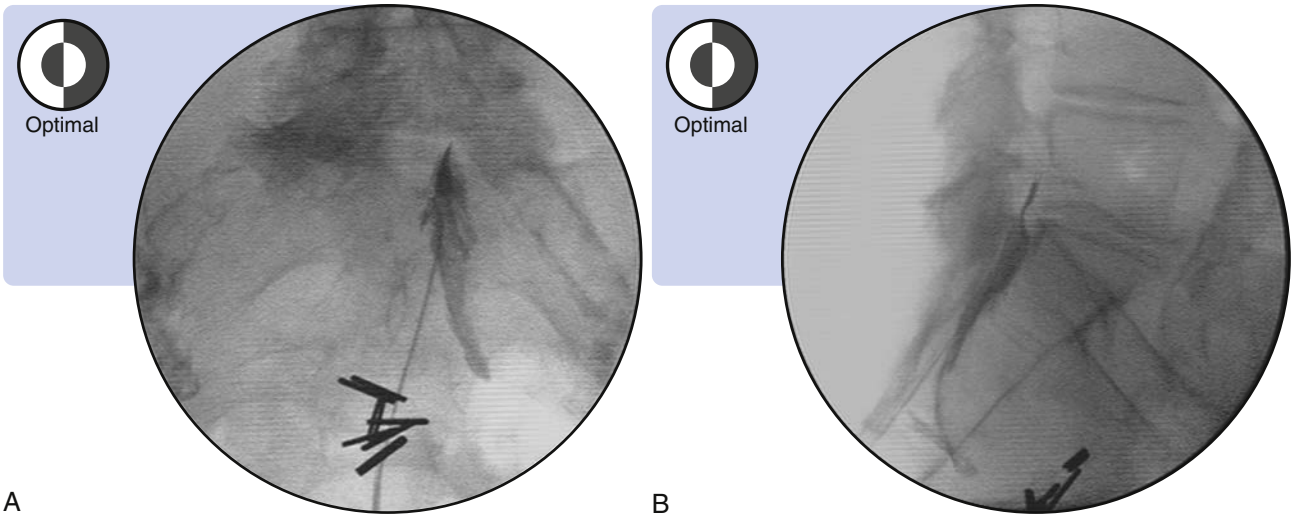

Fig. 7A.5. A, Caudal epidural steroid injection (ESI) with a catheter, anteroposterior view. Note that the catheter is advanced past the needle tip and L5-S1 surgical site. **B,** Caudal ESI with a catheter, lateral view. Note that the catheter is advanced past the needle tip and the L5-S1 surgical site.

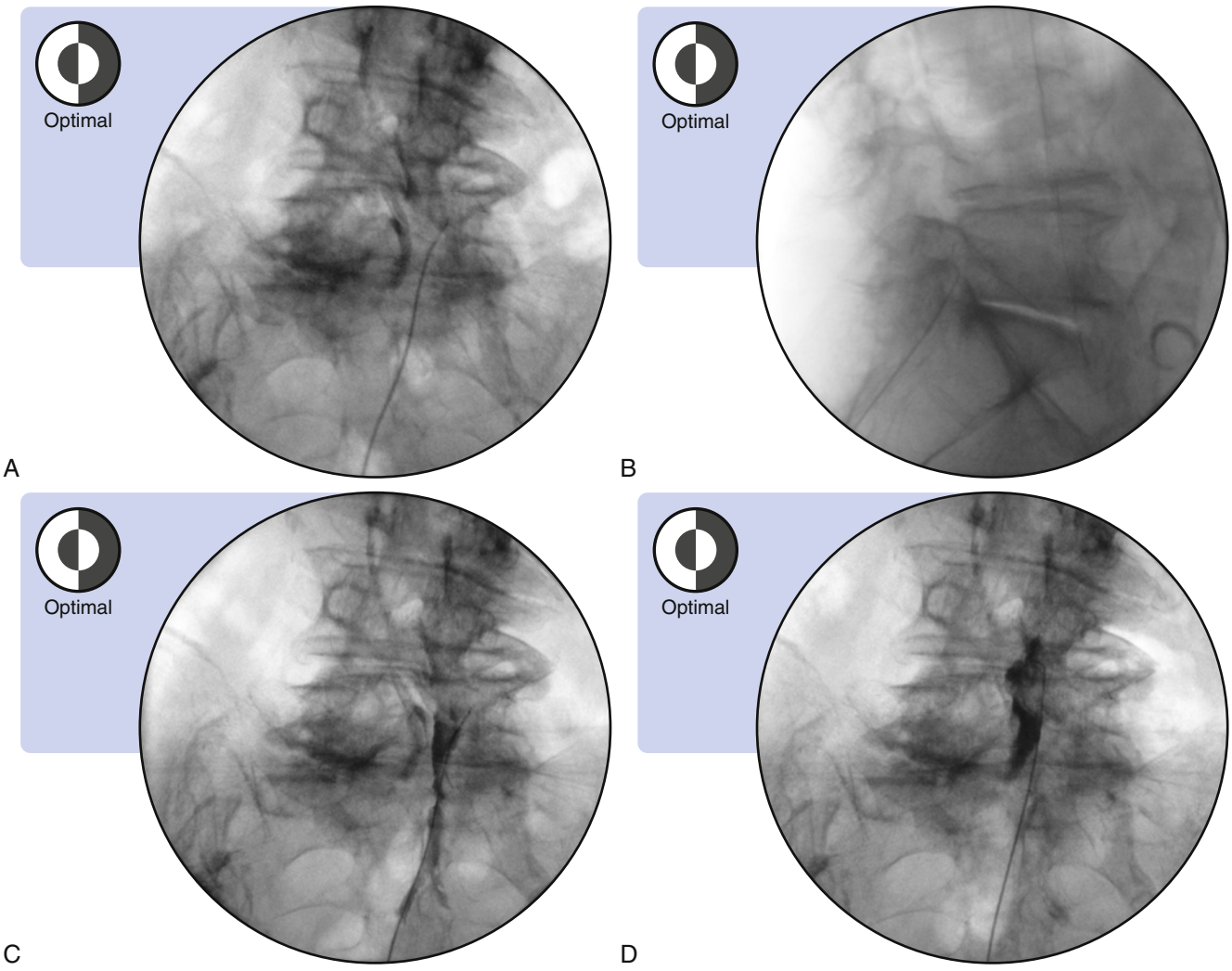

Fig. 7A.6. A, Caudal epidural steroid injection (ESI) with a catheter, anteroposterior view. Note that the catheter is advanced toward the L5 segment, which has significant spondylotic changes, and associated central and foraminal stenosis. **B,** Caudal ESI with a catheter, lateral view. Note that the catheter is advanced past the needle tip. **C,** Caudal ESI with a catheter, anteroposterior view with contrast. Note that the contrast can concentrate to the region close to the catheter tip. **D,** Caudal ESI with a catheter driven more superiorly, anteroposterior view with contrast. The catheter was driven even more superiorly to bathe the region. Note: The catheter caudal ESI technique may be used for lysis of adhesions if the appropriate injectate is placed.

Suboptimal Needle Placement and Images (Figs. 7A.7 to 7A.9)

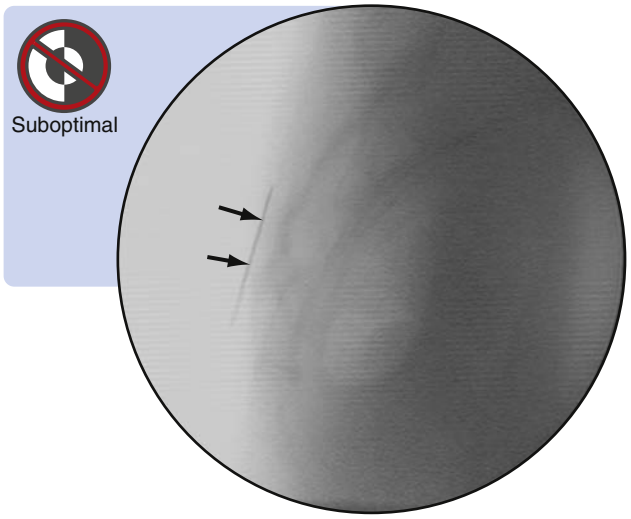

Fig. 7A.7. Needle entry that is too shallow and dorsal to the sacrum.

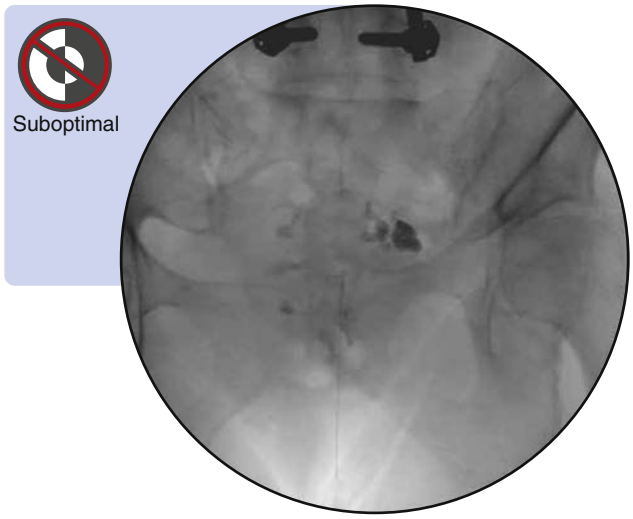

Fig. 7A.8. Note the lack of the proximal flow of contrast despite proper needle placement.

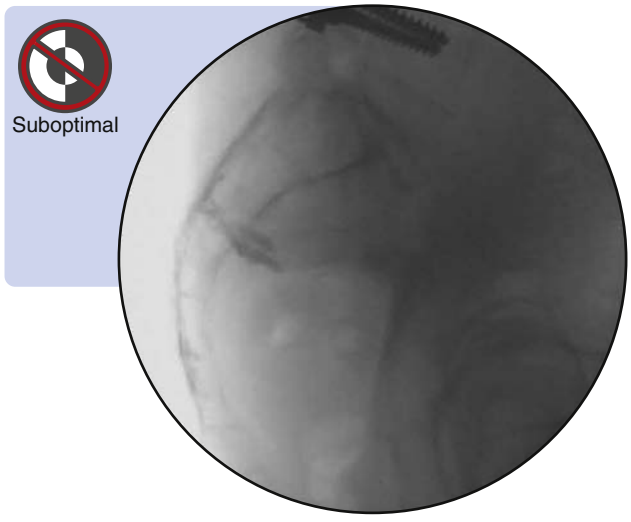

Fig. 7A.9. Note the suboptimal flow of contrast through the sacral foramen despite proper epidural needle placement. A catheter may be required to reach higher levels in this case.

CHAPTER 7B

Caudal Epidural Steroid Injection—Steep Angle Approach: Fluoroscopic Guidance

Denise Norton, Isaac Cohen, and Michael B. Furman

In this technique, the AP view serves as the trajectory view, and also as a multiplanar view. The AP view is used to keep the needle midline and avoid advancing the needle too far cephalad. Appropriate needle tip depth is confirmed with the lateral view, demonstrating needle tip in the sacral canal without overpenetration. The injectate volume can be determined after observing cephalad contrast flow relative to target structures.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 7B.1)

The Trajectory View Is Also a Multiplanar View

- The AP view is the trajectory view
- Confirm the level with the anteroposterior (AP) view.
- Adjust the C-arm tilt to square off the superior end plate of the L5 vertebral body (using cephalad and caudal tilt), and the C-arm rotation (oblique) to position the L5 spinous process equidistant from the L5 pedicles to obtain a true AP view.
- Place a metallic marker over the radiographic midline using the L5 spinous process and median sacral crest.
- Move the C-arm caudad to center the hyperlucent sacral notch in the field of view. The sacral notch is located midline, with the apex of the notch usually at about the S4 level.
- Advance the needle down the beam into the sacral notch.
- The needle will pass through the sacrococcygeal ligament and abut the anterior sacral plate, a hard bony stop.

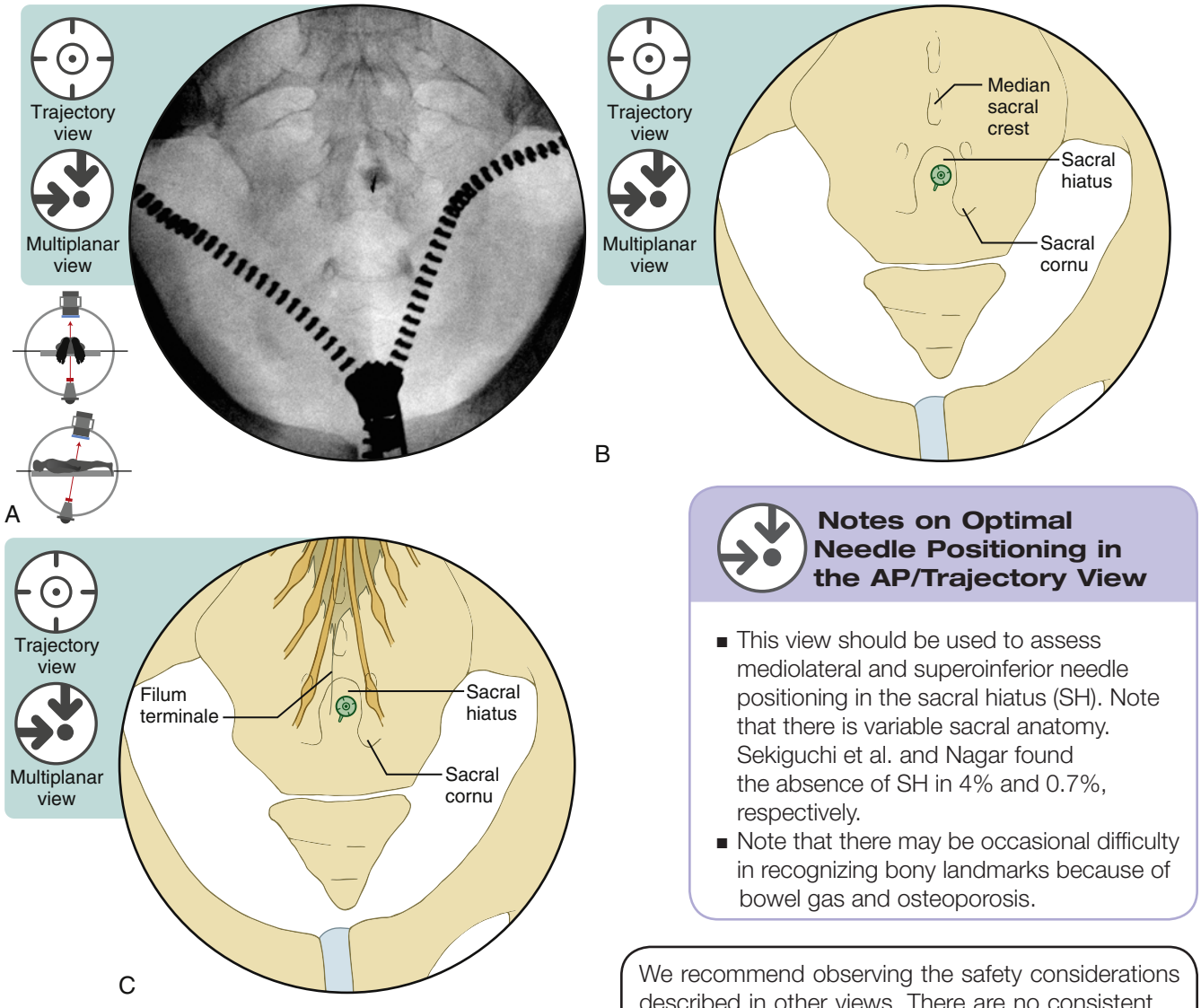

Fig. 7B.1. A, Fluoroscopic image of the trajectory view with the needle in position within the sacral hiatus in the caudal epidural space. **B,** Radiopaque structures, anteroposterior/trajectory view. **C,** Radiolucent structures, anteroposterior/trajectory view.

Notes on Optimal Needle Positioning in the AP/Trajectory View

- This view should be used to assess mediolateral and superoinferior needle positioning in the sacral hiatus (SH). Note that there is variable sacral anatomy. Sekiguchi et al. and Nagar found the absence of SH in 4% and 0.7%, respectively.
- Note that there may be occasional difficulty in recognizing bony landmarks because of bowel gas and osteoporosis.

We recommend observing the safety considerations described in other views. There are no consistent safety considerations in this view.

Optimal Needle Positioning in Multiplanar Imaging (Fig. 7B.2)

- The two views for needle advancement are AP and lateral.
- The C-arm can remain in the AP/trajectory view until the needle has reached its target. Once achieved, a lateral view is obtained to confirm the proper placement of the needle tip within the sacral canal.
- The contrast is then injected in this view under real-time fluoroscopy. (See "Optimal Needle Positioning" below.)
- Return to the AP view to confirm cephalad contrast flow.

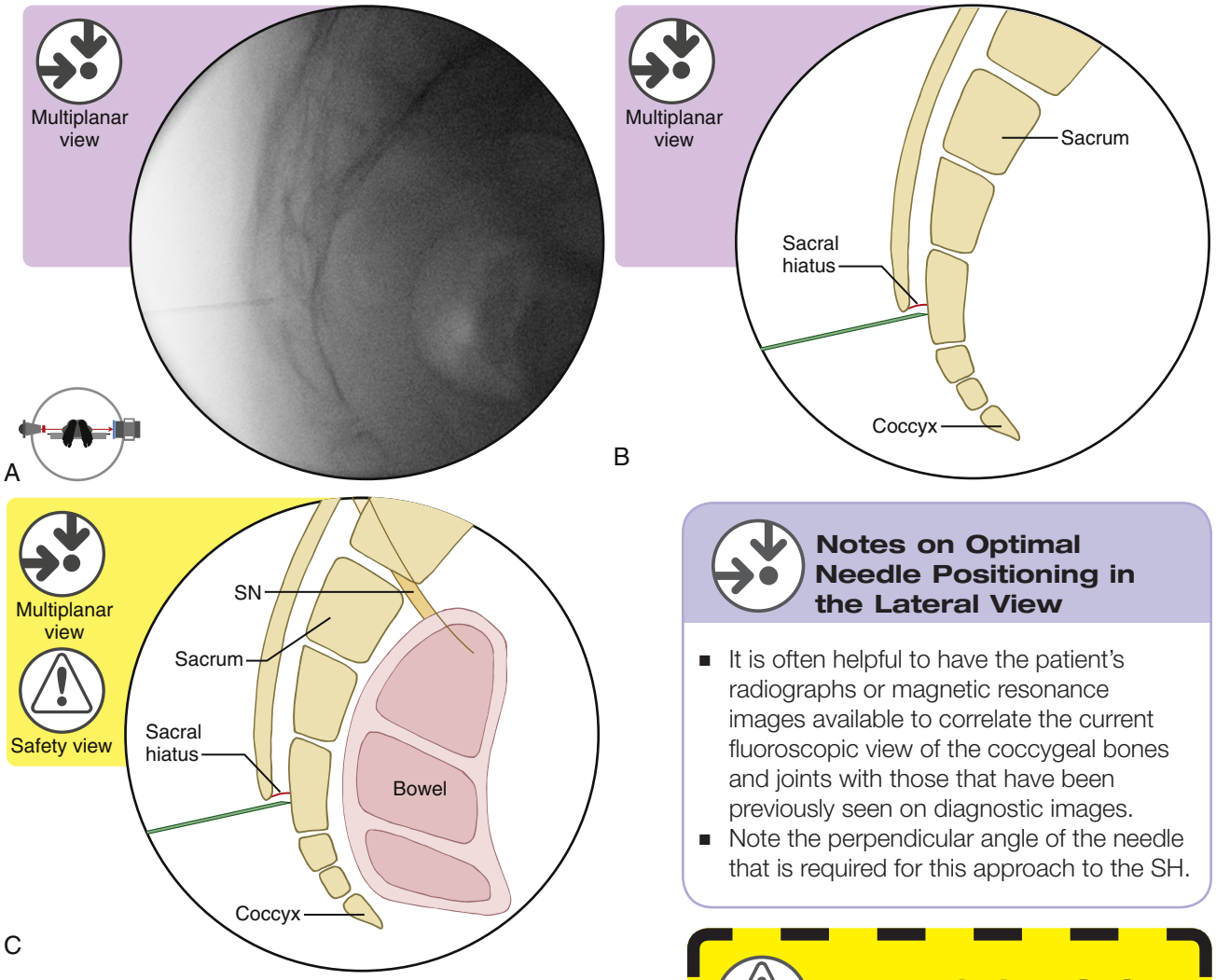

Fig. 7B.2. A, Fluoroscopic image of the lateral view with the needle in position within the sacral hiatus in the caudal epidural space. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Notes on Optimal Needle Positioning in the Lateral View

- It is often helpful to have the patient's radiographs or magnetic resonance images available to correlate the current fluoroscopic view of the coccygeal bones and joints with those that have been previously seen on diagnostic images.
- Note the perpendicular angle of the needle that is required for this approach to the SH.

Lateral View Safety Considerations

- The lateral view confirms that the needle tip depth is not too far ventral, where it may puncture viscera.

Optimal Images (Fig. 7B.3)

- The contrast should spread cephalad for two or more levels. However, this may be limited in cases of central stenosis or prior surgery.
- Epidural fat gives an irregular appearance.

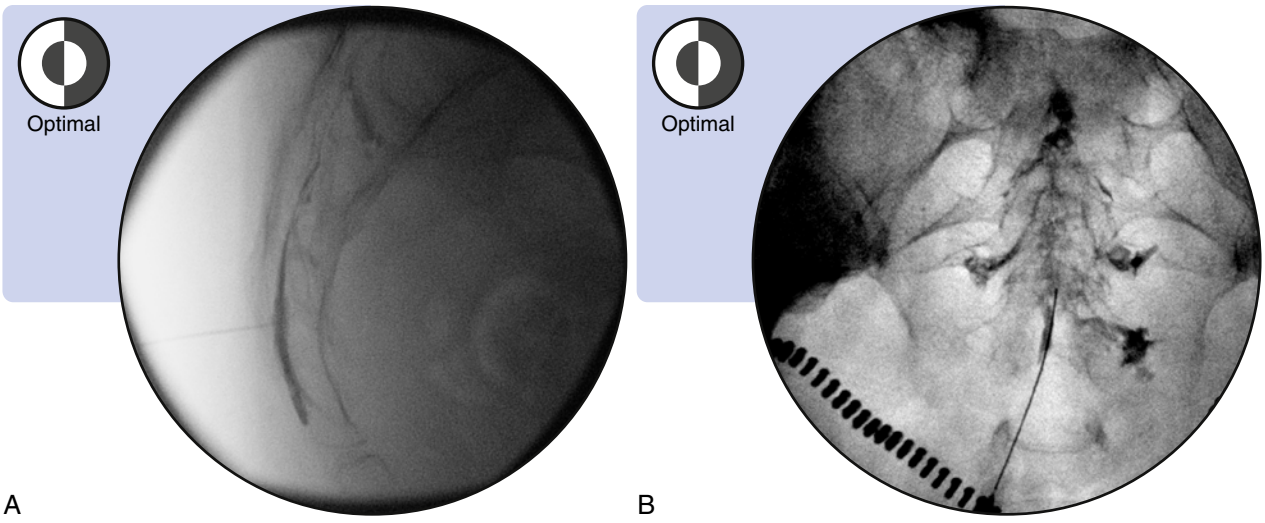

Fig. 7B.3. A, Lateral fluoroscopic image of a caudal epidural steroid injection with contrast. **B,** Anteroposterior fluoroscopic image of a caudal epidural steroid injection with contrast.

Suboptimal Needle Placement and Images

- This approach may result in the contrast not flowing cephalad enough.
- Fig. 7B.4 reveals diversion of contrast predominantly along the right ventral S3 ramus, with no flow cephalad to the S2 segment.

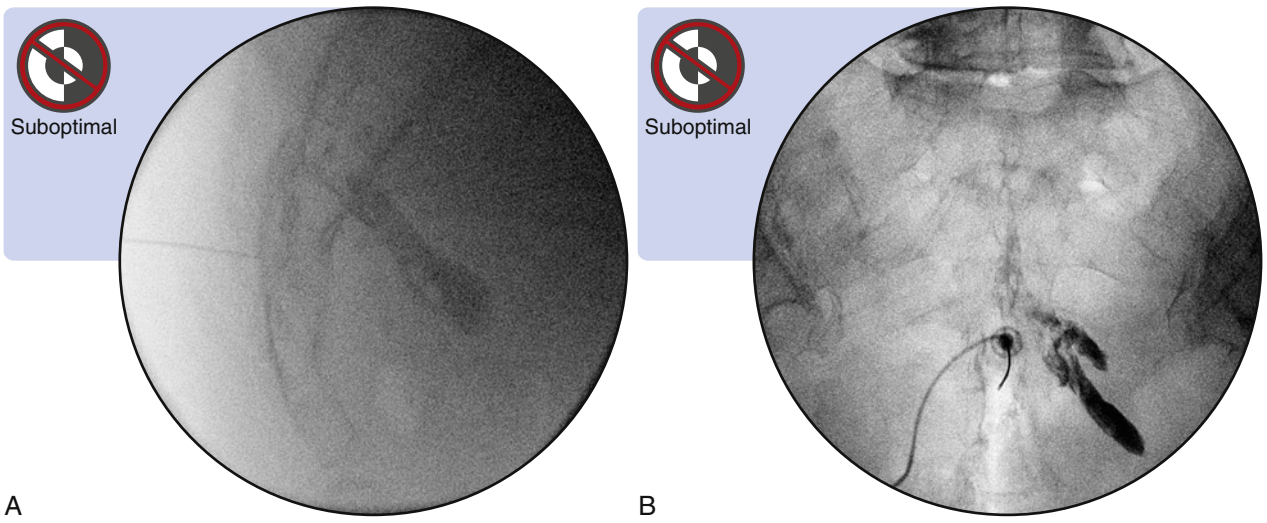

Fig. 7B.4. Suboptimal fluoroscopic images of contrast predominantly along the right ventral S3 ramus, with no flow cephalad to the S2 segment. **A,** Lateral. **B,** Anteroposterior.

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CHAPTER 7C

Caudal Epidural Steroid Injection: Ultrasound Guidance

Denise Norton, Paul S. Lin, and Michael B. Furman

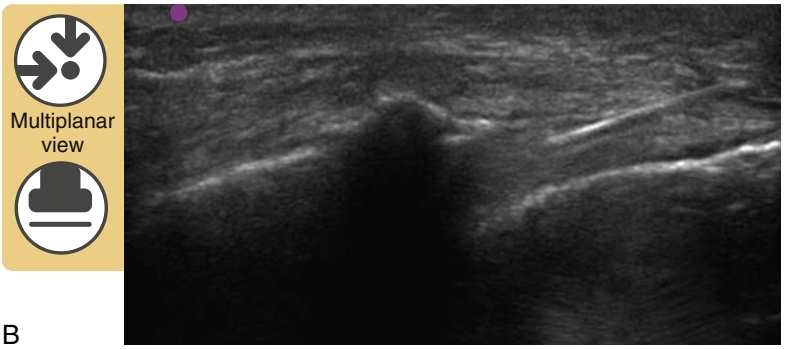
This approach utilizes ultrasound for sacral cornua identification and allows driving live under in-plane guidance into the caudal epidural space. This view is similar to a fluoroscopic lateral view but with no radiation.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 7C.1)

- Have the patient in the prone position and place pillows under the pelvis to help with anatomic visualization.
- Ultrasound image on the opposite side as interventionist and in line with the transducer (see Fig 7C.1A and Chapter 4).
- Utilize a curvilinear transducer for patients with more posterior adipose tissue and a gel stand off for patients with limited adipose tissue (not shown).
- If the tissue obscures the transducer, consider taping the buttocks laterally to obtain the appropriate field for needle placement.
- Tent the patient's skin prior to needle insertion.
- Palpate the sacral hiatus with a sterile gloved hand. This is the entry point for the spinal needle. The sacral hiatus should be palpated prior to placing the ultrasound probe.
- Begin with the transducer in the short axis to the sacrum, midline and proximal to the sacral hiatus, and then track distally over the two sacral cornua. The sacral cornua appear as two hyperechoic reversed U-shaped structures. In the center of the image is a hypoechoic region, the sacral hiatus, bordered by two hyperechoic bands, the sacrococcygeal ligament superiorly and the dorsal surface of the sacrum inferiorly.
- Rotate the transducer by 90 degrees with the long axis to the sacrum, visualizing the sacrum and sacral canal.
- Insert the spinal needle from caudad to cephalad into the sacral epidural space with an in-plane technique. A "pop" is felt once the sacrococcygeal ligament is pierced.
- Scan the needle and sacral hiatus in long and short axes to verify that the needle is traveling along the midline. The needle tip can also be directed to allow the injectate toward the more symptomatic side.
- The initial placement can be made in short axis, out-of-plane, and rotating 90 degrees to confirm the placement before advancing in long axis in-plane.
- Once the needle is advanced into the sacral canal, within the caudal epidural space, it cannot be visualized with ultrasound.

Fig. 7C.1. A, Room and interventionalist setup for injection.



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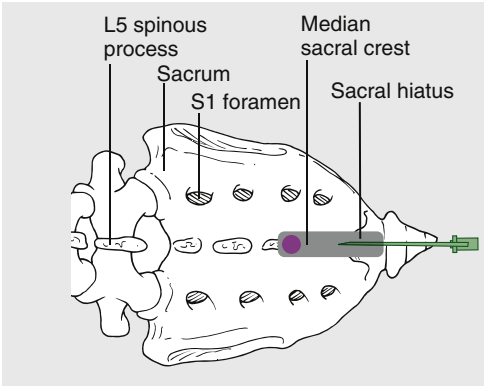

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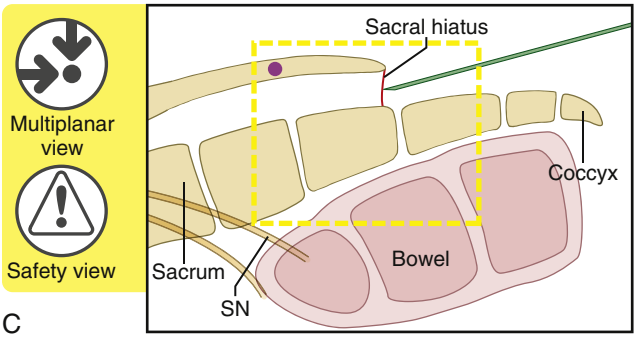

C

Fig. 7C.1. **B,** Ultrasound image of caudal epidural needle placement within the sacral canal in-plane or long axis. **C,** Drawing of relevant radiolucent structures. Yellow dashed line represents borders of the image seen on ultrasound in Fig. 7C.1A. Note the intestine in pink, which is not visible with ultrasound. **D,** Skeleton with the probe. Proper placement of ultrasound transducer for in-plane or long-axis placement.

In-Plane Technique Safety Considerations

- Too steep of an entry angle will not allow needle entry superiorly into the sacral canal. This is a common mistake when first performing this injection.
- A steep trajectory angle has more potential to pass through the sacrum into the viscera.
- Stay below S3 to avoid dural puncture.

Out-of-Plane Confirmation (Fig. 7C.2)

- After epidural placement with in-plane technique, rotate the probe 90 degrees to an out-of-plane, short-axis view to reconfirm the epidural needle tip position.
- This view is helpful to ensure that the needle is midline or ipsilateral to the side of pain depending on clinical goals.

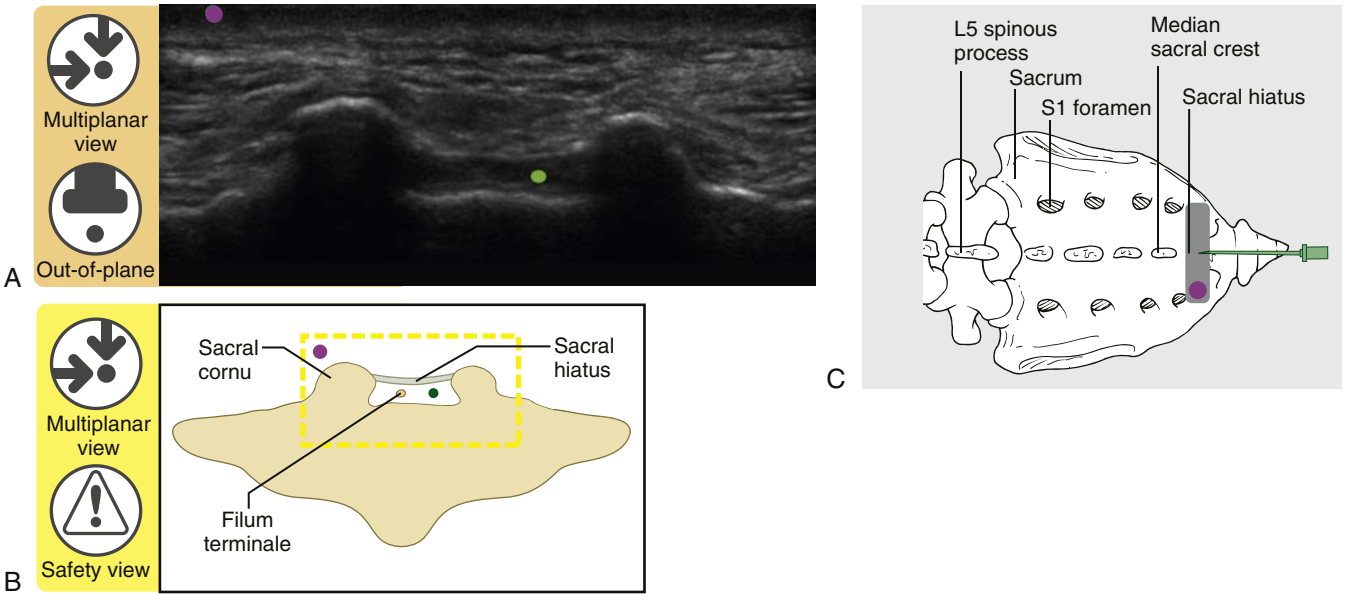

Fig. 7C.2. A, Ultrasound image of the sacral canal with the spinal needle in the caudal epidural space in short-axis, out-of-plane confirmation. **B,** Drawing of relevant structures. Yellow dashed line represents borders of image seen in Fig. 7C.2A. Note the yellow dot within the sacral canal; this represents the filum terminale, which is not visible with ultrasound. **C,** Skeleton with probe. Proper placement of ultrasound probe for out-of-plane or short-axis confirmation.

Out-of-Plane Technique Safety Considerations

- Same considerations as for the in-plane technique.

Optimal Images

- Placement in the epidural space is confirmed with contrast-enhanced real-time fluoroscopy.
- Ideally, the contrast flow should be more localized to the symptomatic side.
- Epidural fat gives an irregular appearance.
- The contrast should spread cephalad to the symptomatic level. However, this may be limited in cases of central stenosis or prior surgery.

For optimal and suboptimal fluoroscopically guided images, see Chapter 7A, Caudal Epidural Steroid Injection—Shallow Angle Approach.

Suboptimal Image (Fig. 7C.3)

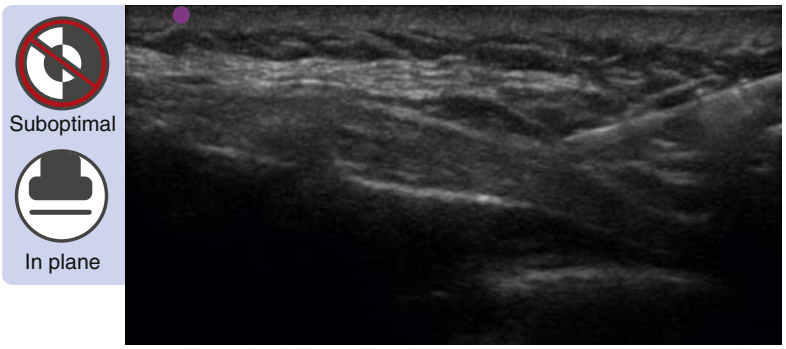

Fig. 7C.3. Ultrasound image of needle too shallow. Epidural access will not be achieved without needle repositioning.

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Ganglion Impar Injection

CHAPTER 8

The ganglion impar (i.e., the ganglion of Walther) is the most inferiorly located of all the ganglia of the sympathetic nervous system. It is the only sympathetic ganglion that is solitary and midline (rather than paired, like the right and left paravertebral). The ganglion impar is located just anterior to the upper coccyx or the lower sacrum in the retrorectal space.

The ganglion impar has been implicated in "sympathetically maintained" pain in the pelvic region. Ganglion impar injections have been reported to be useful for relieving pelvic and perineal pain that is caused by either malignant intrapelvic pathology (e.g., prostate, cervical, and colon cancers) or nonmalignant pathology (e.g., coccydynia aka coccygodynia and chronic rectal pain). The underlying cause of the pain should be evaluated before administering these injections, and this evaluation should include screening for underlying pelvic malignancies and gastrointestinal, gynecologic, or urologic dysfunction.

The techniques in these chapters describe approaching the ganglion impar through the sacrococcygeal or intercoccygeal disc space. Paracoccygeal and anococcygeal approaches will also be briefly discussed in the fluoro chapter. The interventionalist may determine which space to access depending on the extent of osteoarthritic or degenerative disc changes.

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3. Foye PM, Patel SL. Paracoccygeal corkscrew approach to ganglion impar injections for tailbone pain. *Pain Pract*. 2009;9(4):317–321.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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CHAPTER 8A

Ganglion Impar Injection: Fluoroscopic Guidance

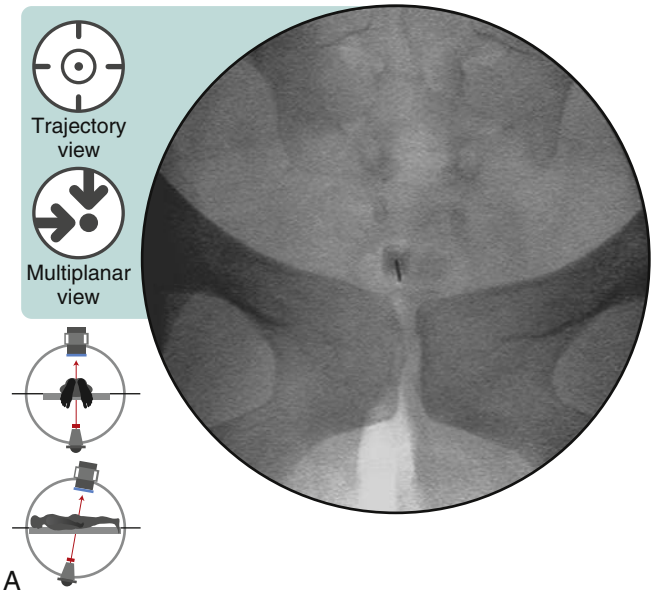
Patrick M. Foye, Jonathan S. Kirschner, and Michael B. Furman

The main safety consideration is to avoid bowel perforation by going too far lateral on the anteroposterior (AP) view or too far ventral on the lateral view. Furthermore, a loss of resistance technique may be utilized to safely pass the ventral sacrococcygeal disc.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View: The Trajectory/Anteroposterior View Is Also a Multiplanar View

- **Confirm the level** (with the cross-table lateral view) by noting any visible landmarks (e.g., the coccygeal cornu, the sacrococcygeal joint, or any intracoccygeal joints) through which the approach may be planned. Mark this site with a skin marker or a metallic pointer. This demonstrates how superior or inferior the block should be initiated.
- The C-arm is then brought to the AP position, and the needle is inserted in the midline at the predetermined superoinferior position, just deep enough to obtain skin purchase and to maintain a perpendicular trajectory needle position "down the beam."
- **Cephalad or caudad tilt of the image intensifier** to "line up" the disc space for entry (Fig. 8A.1).



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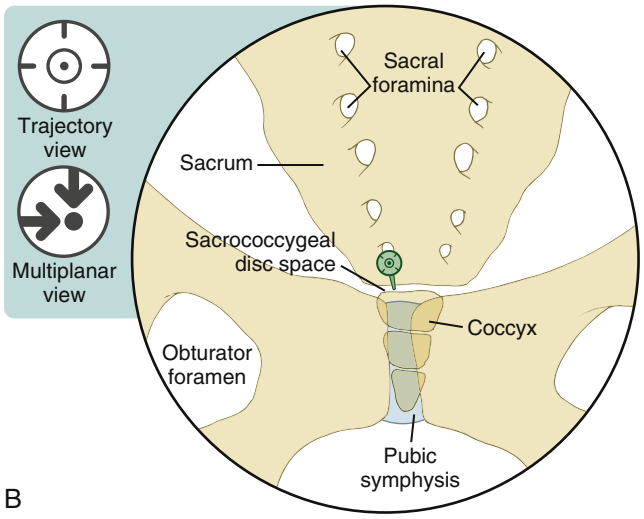

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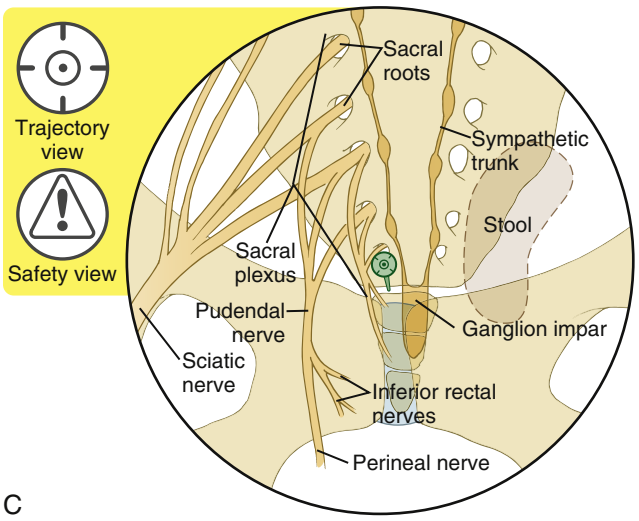


C

Fig. 8A.1. A, Fluoroscopic image of a trajectory view with the needle in position at the sacrococcygeal junction and in line to enter through the center of the disc. **B,** Radiopaque structures, trajectory anteroposterior view. **C,** Radiolucent structures, trajectory anteroposterior view.

Notes on Optimal Needle Positioning in the Multiplanar Trajectory/Anteroposterior View

- This view should be used only to assess the mediolateral and superoinferior needle position. It should not be used for any substantial ventral needle advancement.
- Direct the needle midline to access the ganglion impar.

Trajectory/Anteroposterior View Safety Considerations

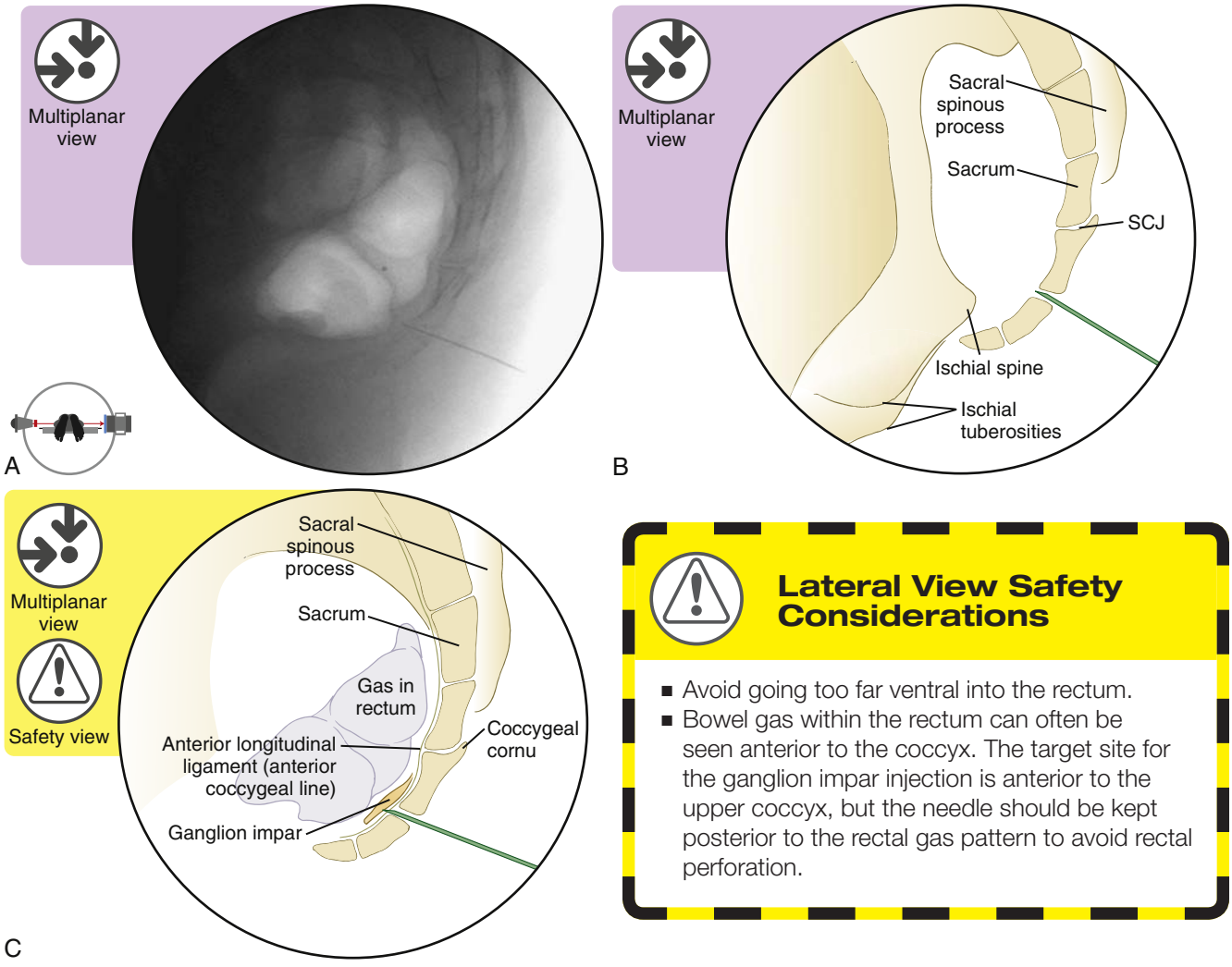
- If the needle strays from the midline, it may potentially cause the inadvertent blockade of other pelvic nerves or rectal perforation.

Optimal Needle Positioning in Multiplanar Imaging

- The two views for needle advancement are AP and lateral.
- The C-arm can remain in the lateral view throughout most of the procedure, except for briefly checking an the AP view to confirm that the needle tip, the contrast, or both have appropriate midline placement. The AP view can be especially helpful if the lateral view shows a contrast flow pattern that is suboptimal or atypical.

LATERAL VIEW (FIG. 8A.2)

- The C-arm should be oriented to obtain a "true" lateral (see Chapter 3). This is important for assessing the association of the needle to the proximity of the anterior coccygeal line.
- Needle advancement primarily takes place in the lateral view as the dorsoventral depth is visualized. For very tight joint spaces, consider rotating the needle during advancement to slowly "corkscrew" through it.
- The physician may feel a subtle change of resistance when the needle tip passes through the anterior longitudinal ligament (i.e., the anterior sacrococcygeal ligament).



Lateral View Safety Considerations

- Avoid going too far ventral into the rectum.
- Bowel gas within the rectum can often be seen anterior to the coccyx. The target site for the ganglion impar injection is anterior to the upper coccyx, but the needle should be kept posterior to the rectal gas pattern to avoid rectal perforation.

Fig. 8A.2. A, Fluoroscopic lateral view with ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Notes on Optimal Needle Positioning in the Lateral View

- It is often helpful to have the patient's radiographs or magnetic resonance images available to correlate the current fluoroscopic view of the coccygeal bones and joints with those that have been previously seen on diagnostic images.
- The sacrococcygeal joint can sometimes be identified by visualizing the coccygeal cornu, which head superiorly from the posterior aspect of the first coccygeal bone. These cornu point toward the sacral cornu, which are angled inferiorly from S5, the fifth sacral segment.
- Intracoccygeal approaches to the ganglion impar are easiest when the initial entrance into the joint has a trajectory that is well aligned with the joint space.

Optimal Images (Fig. 8A.3)

LATERAL VIEW

- The contrast flow should stay dorsal to the rectal gas pattern but anterior to the coccyx.

ANTEROPOSTERIOR VIEW

- The contrast flow should be midline. When the needle tip is anterior to the ventral aspect of the coccyx, as seen in the lateral view, and when it is midline, as seen in the AP view, then the lateral view is used during a live contrast injection. The AP view can then be used to confirm that the flow is midline.

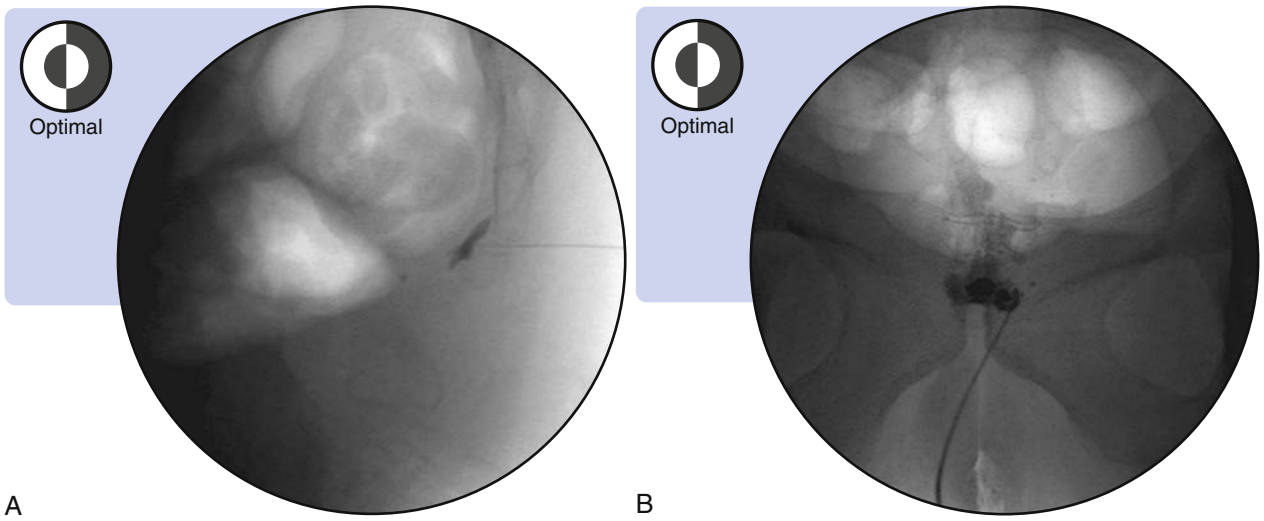


Fig. 8A.3. A, Lateral fluoroscopic image of a ganglion impar injection showing contrast flow just anterior to the upper coccyx. **B,** Anteroposterior fluoroscopic image of a ganglion impar injection showing contrast flow in the midline at the upper coccyx. The view is partially obstructed by the pubic bones as well as by gas and stool within the rectum.

Suboptimal Images (Figs. 8A.4 to 8A.9)

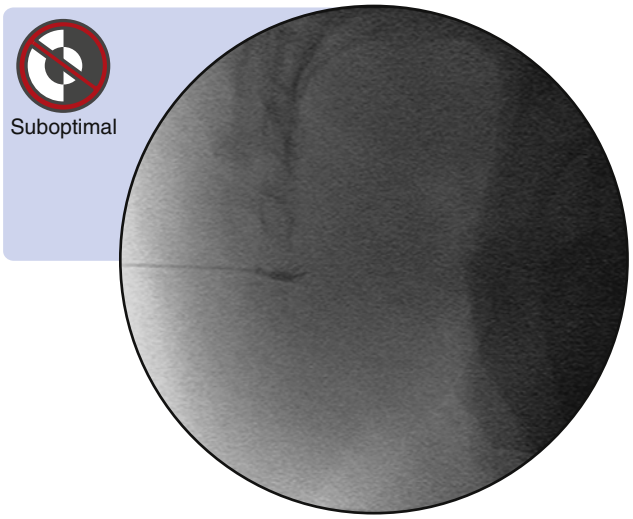


Fig. 8A.4. Suboptimal ganglion impar injection in the lateral view showing that the needle tip has not advanced far enough and that it is still in one of the intracoccygeal disc spaces.

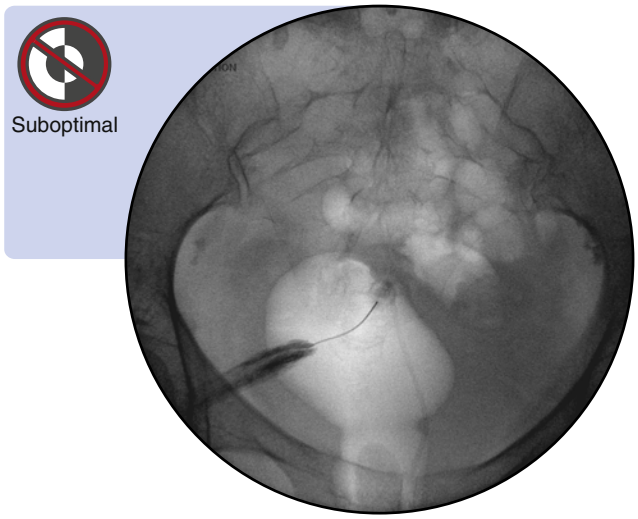


Fig. 8A.5. Suboptimal ganglion impar injection in the antero-posterior view showing that the needle tip has gone too far lateral. Most likely the needle has entered the coccygeal disc space at the angle pointing somewhat laterally (rather than maintaining a midline trajectory). Thus, it can be seen that the needle hub is still relatively midline, but the needle tip has advanced too far laterally. The contrast pattern further confirms the lateral placement because the contrast outlines unilateral pelvic floor muscles rather than remaining midline at the coccyx.

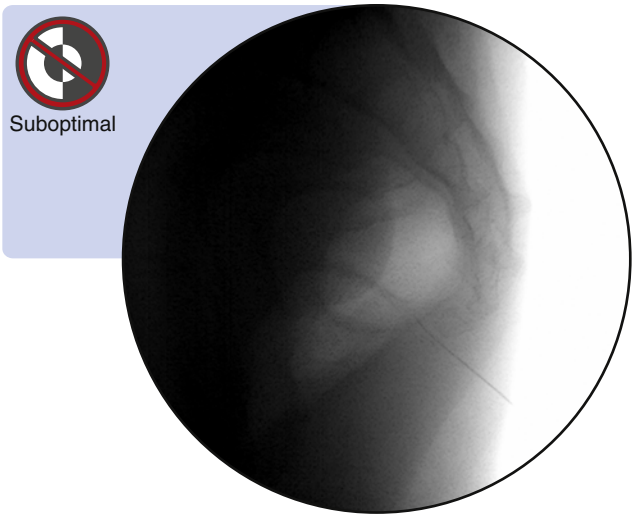


Fig. 8A.6. Suboptimal ganglion impar injection in the lateral view showing that the needle tip has gone too far anterior, potentially perforating the rectum.

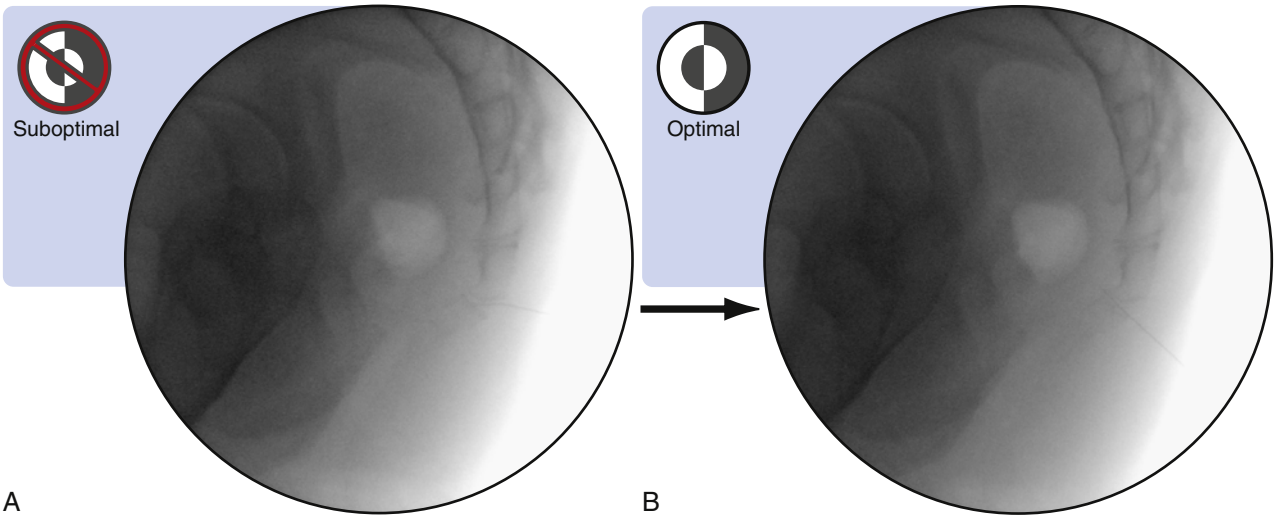


Fig. 8A.7. A, Fluoroscopic image with the needle in a suboptimal position at the Cx1-Cx2 joint space (i.e., between coccygeal segments 1 and 2). The trajectory, which is shown by the shaft of the needle, has easily passed the needle through the posterior aspect of the joint space, but difficulty will occur with regard to further advancement through the anterior aspect of the joint space. **B,** Fluoroscopic image with the needle in an optimal position at the Cx1-Cx2 joint space. Note that the trajectory, which is shown by the shaft of the needle, has been modified from the prior image so that a straight pass can now be made through the entire coccygeal disc space to more easily exit that disc anteriorly.

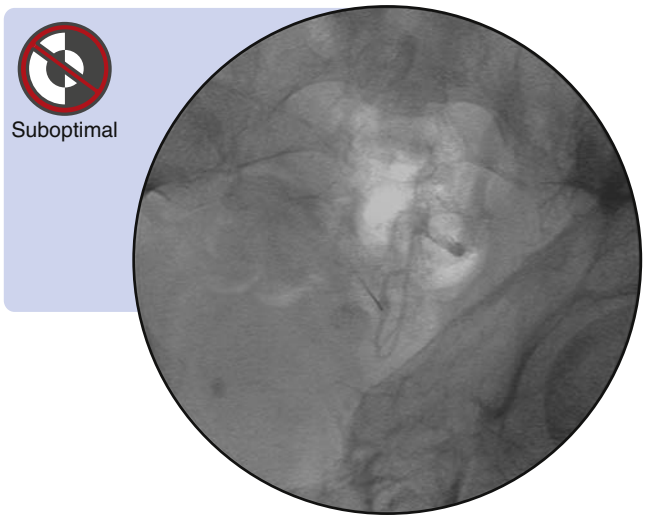


Fig. 8A.8. Fluoroscopic anteroposterior image showing an inadvertent vascular pattern at the anterior sacrum and coccyx, rather than the desired flow pattern. Note that this is not a "true" anteroposterior view but instead is somewhat oblique, as evidenced by the asymmetric appearance of the hip joint and the ischium on the lower side of the image.

SUPPLEMENTAL APPROACHES AND ILLUSTRATIONS

There are four main anatomic approaches to consider when performing ganglion impar blocks:
1. Approaching via the anococcygeal ligament (i.e., just above the anus and below the coccyx)
2. Going through the sacrococcygeal joint
3. Going through the intracoccygeal joints
4. Paracoccygeal approaches (i.e., immediately to the right or left of the coccyx)

As an overview, Fig. 8A.9 demonstrates approaches 1, 2, and 3, and Fig. 8A.10 shows the paracoccygeal approach. The previously described direct trajectory technique is ideal for going through the sacrococcygeal or intracoccygeal joints. It has been demonstrated to be safe and effective, and it makes use of the shortest needle that can reach the intended target.

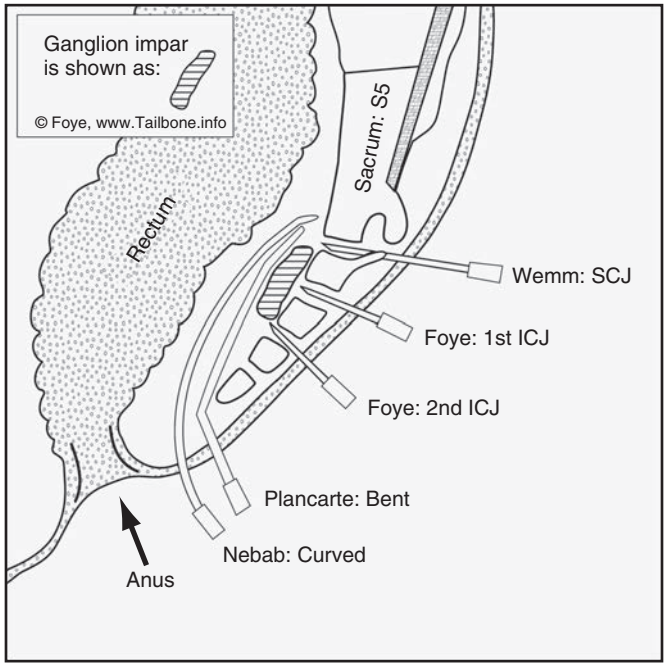


Fig. 8A.9. Various ganglion impar injection techniques, with notations made about physicians who published them. Older techniques approached through the anococcygeal ligament with the use of a needle that was either bent (Plancarte) or curved (Nebab). More recent approaches include inserting the needle through the sacrococcygeal joint (*SJC*, by Wemm), the first intracoccygeal joint (*1st ICJ*, by Foye), or the second intracoccygeal joint (*2nd ICJ*, by Foye). Diagrammatically, the lower rectum is drawn more anterior than its real anatomic location, which is just barely anterior to the coccyx. *(Reprinted with permission. Image © Patrick M. Foye, MD. www.tailbone.info)*.

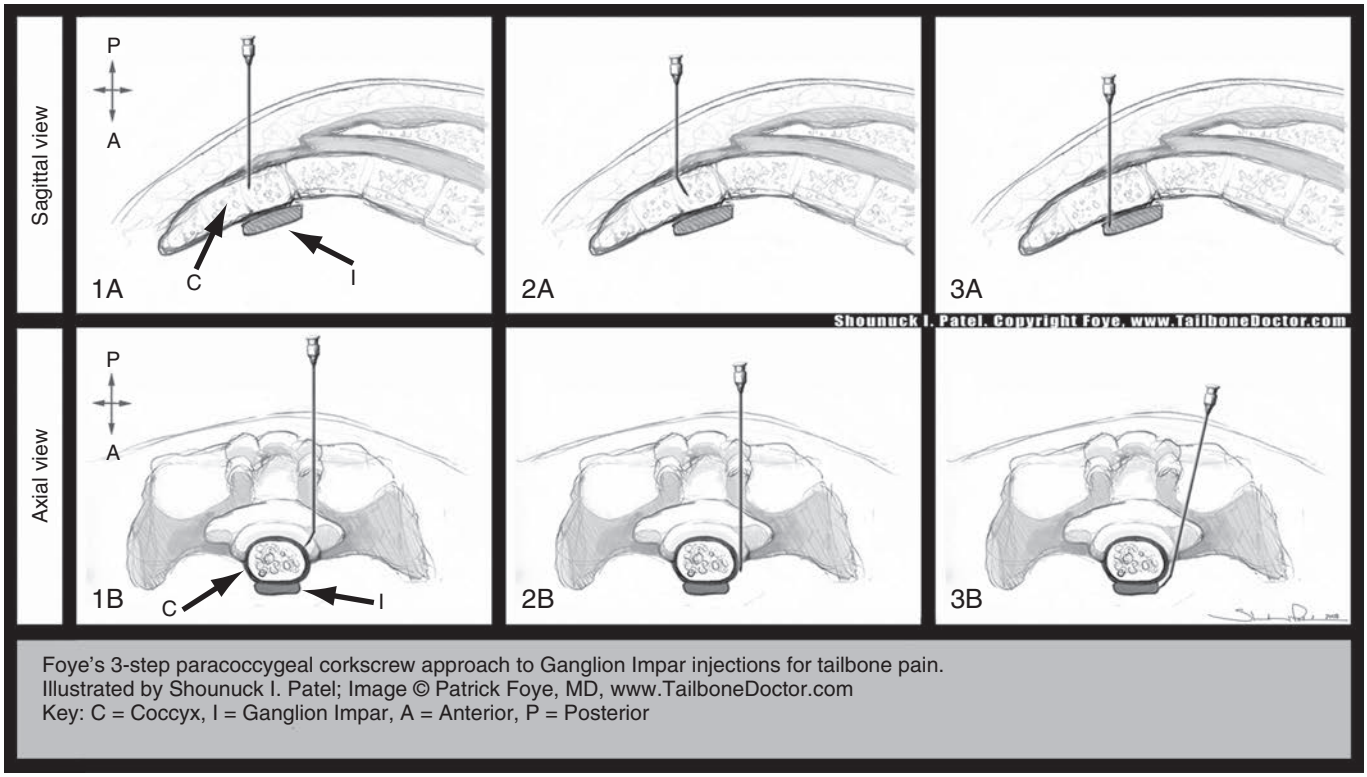


Fig. 8A.10. Foye's three-step paracoccygeal corkscrew approach to ganglion impar injection. Because the paracoccygeal approaches are much less commonly used (partly because they are technically more difficult), they are not discussed in detail within this book. *A,* Anterior; *C,* coccyx; *I,* ganglion impar; *P,* posterior. *(Reprinted with permission. Illustrated by Shounuck I. Patel. Image © Patrick M. Foye, MD. www.tailbonedoctor.com.)*

Reference

1. Foye PM, Patel SI. Paracoccygeal corkscrew approach to ganglion impar injections for tailbone pain. *Pain Pract*. 2009;9(4):317–321.

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CHAPTER 8B

Ganglion Impar Injection: Ultrasound Guidance

Christopher Bednarek, Paul S. Lin, and Michael B. Furman

Ultrasound may be utilized to assist in locating the sacrococcygeal disc space and decreasing the radiation exposure associated with a purely fluoroscopic approach. Despite these benefits, ultrasound cannot consistently visualize structures (especially the needle tip) anterior to the sacrococcygeal line. The hybrid procedure (US placement with contrast-enhanced fluoroscopy) improves safety by recognizing and avoiding vascular uptake and injection of visceral structures.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

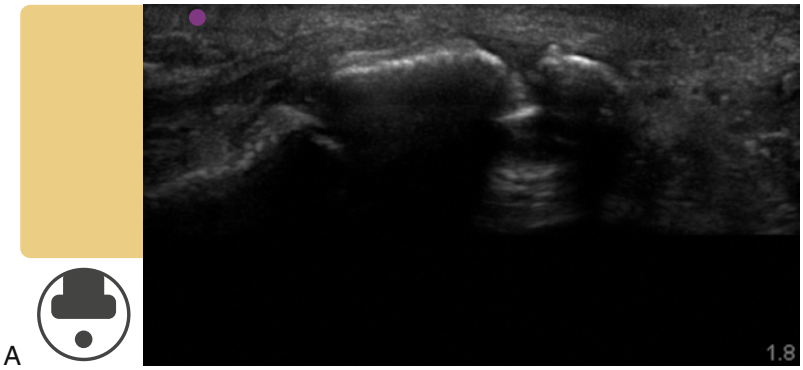
Out-of-Plane Technique

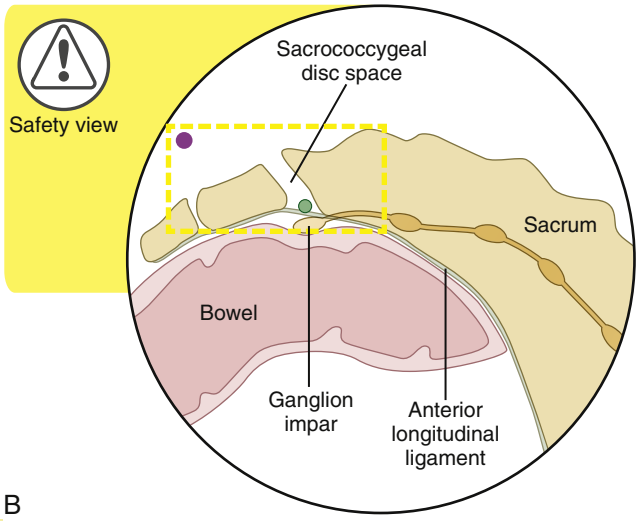
- Patient is prone with appropriate positioning (see Fig. 8B.1).
- If necessary, consider taping the buttocks laterally to improve transducer contact.
- Palpate the median sacral crest prior to placing the ultrasound transducer.
- Begin with the transducer midline, long axis to the spine over the median sacral crest and translate inferiorly along the midline osseous structures past the caudal epidural space until the sacrococcygeal and intercoccygeal discs are clearly visualized.
- With the transducer's long axis to the sacrum, insert the spinal needle with an out-of-plane technique into the sacrococcygeal disc space (Fig. 8B.2A–C).
- Loss of resistance technique can be utilized to safely pass the ventral sacrococcygeal disc.

Fig. 8B.1. Prone positioning.

Out-of-Plane Technique Safety Considerations

- If the angle is not parallel with the disc, the needle may touch osseous structures, preventing access to the ganglion impar.
- The needle cannot be reliably visualized with ultrasound beyond the anterior sacrococcygeal disc space. A fluoroscopic lateral view is recommended to reliably visualize the needle depth to avoid the ventrally located bowel.





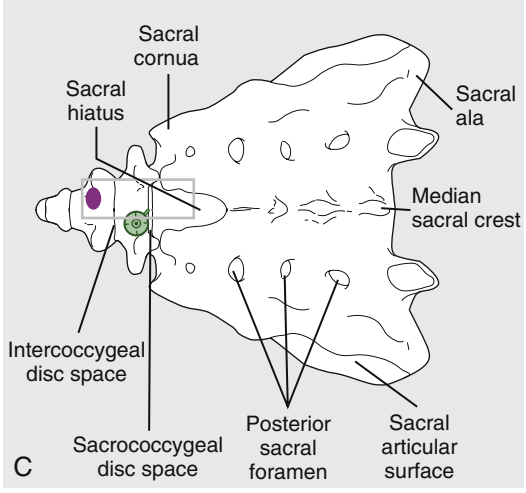


Fig. 8B.2. A, Ultrasound image of spinal needle placement within the sacrococcygeal disc space in long axis. **B,** Drawing relevant radiolucent structures. The yellow dashed line represents borders of the image seen on ultrasound in Figure 1A. Note that the needle is not yet at the ganglion impar target, which is ventral to the anterior longitudinal ligament. In addition, note that the gastrointestinal tract and rectum are not visible with ultrasound. A fluoroscopic lateral view is recommended to reliably visualize needle depth to avoid the ventrally located bowel. **C,** Skeleton with an ultrasound transducer demonstrates proper placement for long-axis confirmation.

Multiplanar View

- We typically do not perform in-plane, multiplanar confirmation for this procedure.

Optimal and Suboptimal Images

For optimal and suboptimal fluoroscopically guided images, please see Chapter 8A, Ganglion Impar Injection: Fluoroscopic Guidance.

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CHAPTER 9

Sacral Insufficiency Fracture Repair/ Sacroplasty

Michael E. Frey and Michael B. Furman

Sacral insufficiency fractures are a common cause of low back pain. They are often underdiagnosed as a result of low clinical suspicion. These fractures are a consequence of the imposition of physiologic stresses onto weakened bones. Spontaneous fracture of the osteoporotic sacrum was first described in 1982. It clinically manifests as back and/or buttock pain with or without lower limb pain referral.

The traditional therapeutic algorithm for sacral insufficiency fractures consists of limited bed rest, partial weight bearing, and early mobilization. The overall 1-year mortality rate associated with pelvic insufficiency fractures is 14.3%, and 50% of affected patients will not return to their prior level of functioning. Despite a favorable natural history, more aggressive treatments may benefit patients who are incapacitated by painful sacral insufficiency fractures.

The percutaneous injection of polymethylmethacrylate (PMA) into fractured vertebral bodies (i.e., vertebroplasty) has been safely performed to successfully treat painful osteoporotic compression fractures. A natural extension of the application of vertebroplasty is the percutaneous injection of synthetic bone cement into the fractured sacrum (i.e., sacroplasty) to treat persistent symptoms and disability.

Several articles have documented the efficacy of sacroplasty, including two large prospective studies. Sacroplasty appears to be a safe and effective treatment for painful sacral insufficiency fractures. The rate of improvement is rapid, with more than 50% reduction in pain achieved before the post-procedure discharge of the patient. Pain reduction primarily occurs within the first 3 months, but it is sustained through 12 months after treatment.

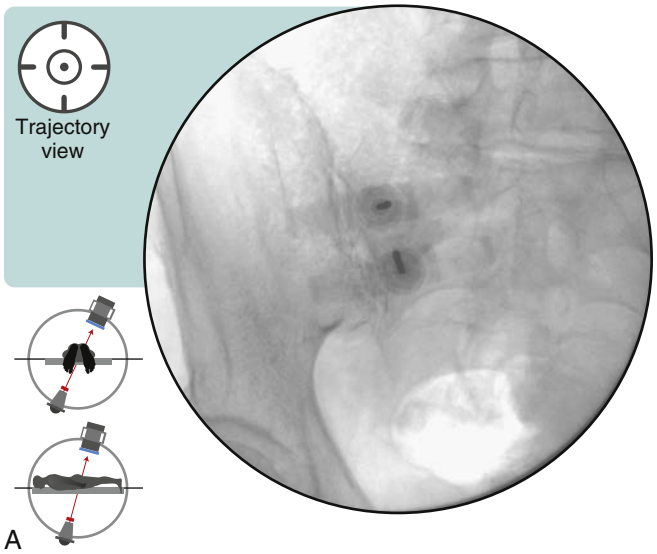
Complications of this procedure include (but are not limited to) bleeding, infection, bowel perforation, cement emboli, and neuritis. With the use of the technique described here, bowel perforation and neuritis can be minimized by using appropriate safety considerations and views.

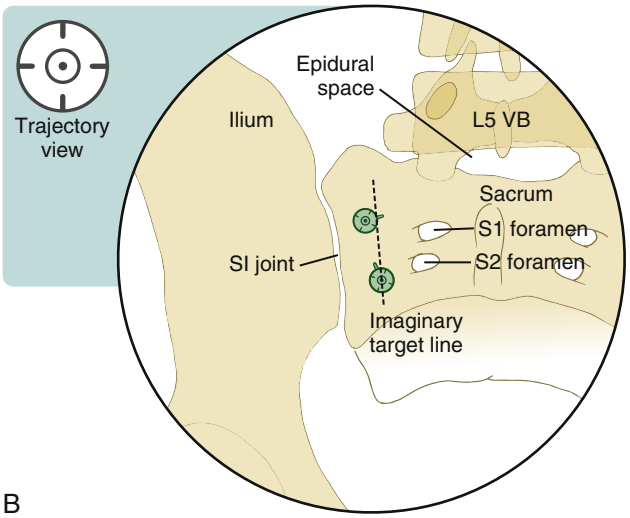
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

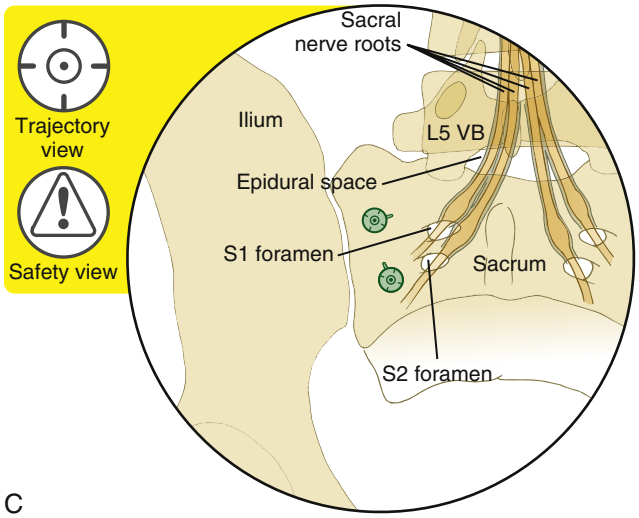
Trajectory View

Confirm the level (with the anteroposterior view) before obtaining the trajectory view.

- The fluoroscope is obliqued contralaterally from the side being treated until one can superimpose the medial and lateral aspects of the sacroiliac joint. This could be approximately 5- to 25-degree contralateral oblique. If the posterior iliac crest is in the way, caudal or cephalad tilts of 0 to 25 degrees may be necessary.
- The needle tip destination is at the midpoint of the imaginary line drawn between the lateral aspect of the dorsal sacral foramina and the sacroiliac joint.
- Use an 18-gauge needle to first penetrate the skin. Use a mallet to gently tap either a 13- or 11-gauge trocar into the periosteum.
- Because this is the trajectory view, the needle entry position should be parallel to the C-arm beam (Fig. 9.1).







Trajectory View Safety Considerations

- Avoid the nerve root and spinal nerve by staying lateral to the lateral aspect of the foramen.

Fig. 9.1. A, Trajectory view with S1 and S2 needle being placed. The fluoroscope is obliqued contralaterally from the side being treated until one can line up the sacroiliac joint. This could involve an approximately 5- to 25-degree oblique tilt. If the posterior iliac crest is in the way, caudal or cephalic tilts of 0 to 25 degrees may be necessary. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

Use anteroposterior and lateral views to confirm trocar placement before placing the PMA.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 9.2)

Check a lateral view to confirm that the needle tip is located within the S1 and S2 vertebral segments and not ventral to them. The C-arm should be oriented to obtain a true lateral view (see Chapter 3).

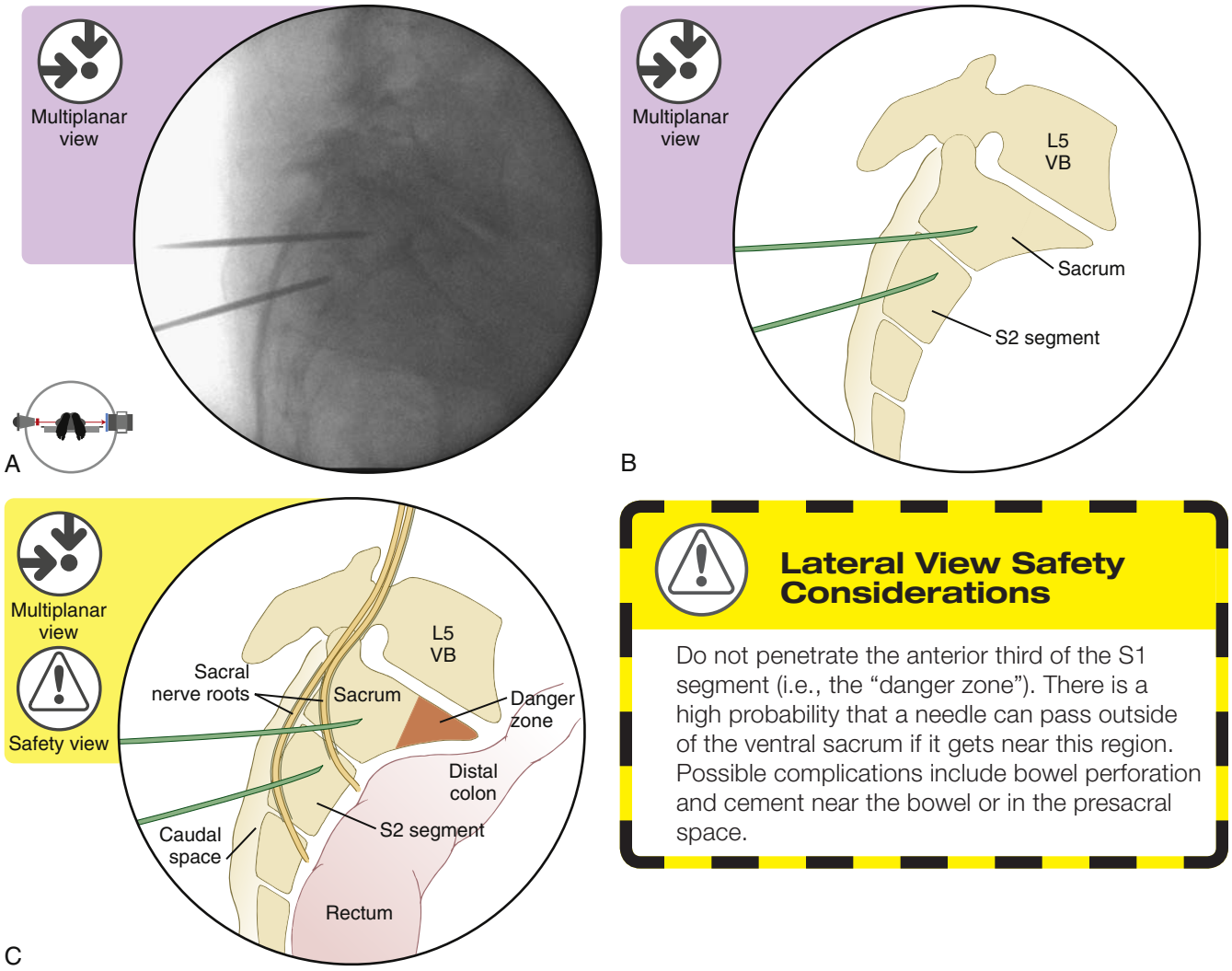

Multiplanar view
A
Multiplanar view
L5 VB
Sacrum
S2 segment
B
Multiplanar view
Safety view
Sacral nerve roots
Sacrum
L5 VB
Danger zone
Distal colon
S2 segment
Caudal space
Rectum
C
Lateral View Safety Considerations
Do not penetrate the anterior third of the S1 segment (i.e., the "danger zone"). There is a high probability that a needle can pass outside of the ventral sacrum if it gets near this region. Possible complications include bowel perforation and cement near the bowel or in the presacral space.

Fig. 9.2. A, Fluoroscopic lateral view of the S1 needle placed. Slowly advance the trocar under continuous imaging to the middle third of the sacrum with the use of the lateral view. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view. This view is used to advance ventrally. The anteroposterior (AP) view (see Fig. 9.1) confirms that the trocars are actually lateral to the nerves.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 9.3)

Return to the anteroposterior view to properly visualize the sacral foramen and to confirm needle tip placement. Some physicians may consider placing contrast at the S1 nerve root for the proper visualization of the nerve.

The same process is repeated at S2. For most patients, needle placement at the S1 and S2 segments is sufficient.

Depending on the extent of the fracture based on magnetic resonance imaging, computed tomography, or bone scan findings, the process may need to be repeated at S3 and S4.

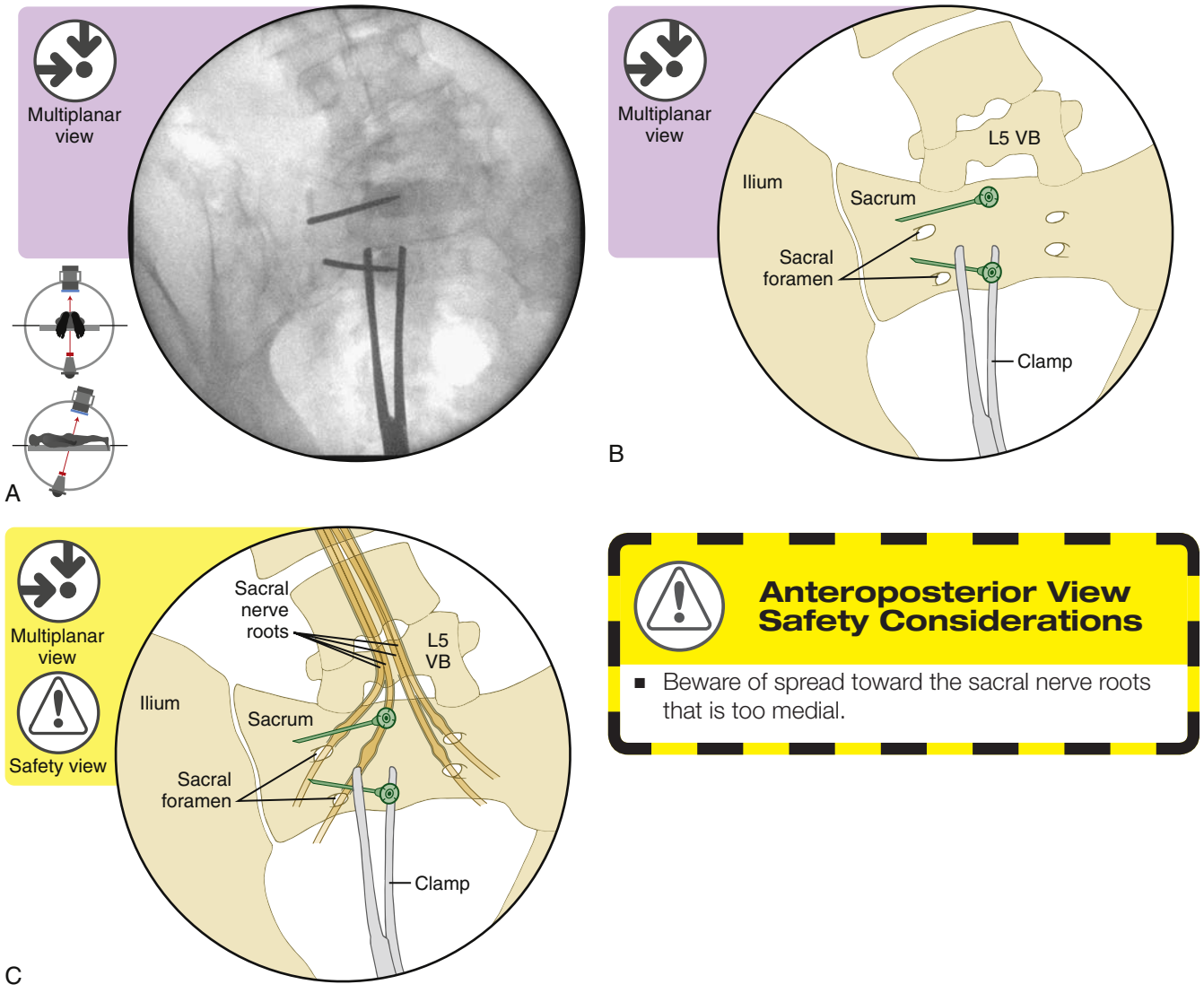


Fig. 9.3. A, Fluoroscopic image of the anteroposterior view with the needle tip in position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view. Although the S2 trocar appears close to the S1 ventral nerve, lateral imaging (Fig. 9.2) confirms appropriate ventral depth and safety.

Optimal Cement Patterns

When injecting the cement, first slowly inject using anteroposterior imaging to watch for medial spread of the cement toward the nerve roots. Some physicians may first want to place the contrast along the sacral nerve root, but this may obscure the proper placement of the cement. Fill most of the S1 and S2 segments where most of the weight-bearing occurs. Consider injecting the S2 segment first because most of the cement travels both down toward the lower sacrum and up toward the S1 segment. As a result of lordosis, the sacrum is in a caudad position when the patient is lying prone. Place approximately 5 to 10 cc of cement in each sacral ala. As described for almost all techniques, multiplanar imaging is recommended and employed in this procedure to monitor the cement spread. This is accomplished by alternating between the lateral and anteroposterior views (Fig. 9.4) or through biplanar fluoroscopy (if available).

Optimal cement patterns travel into most of the sacral alae. The goal is to achieve safe optimum filling of the sacral alae.

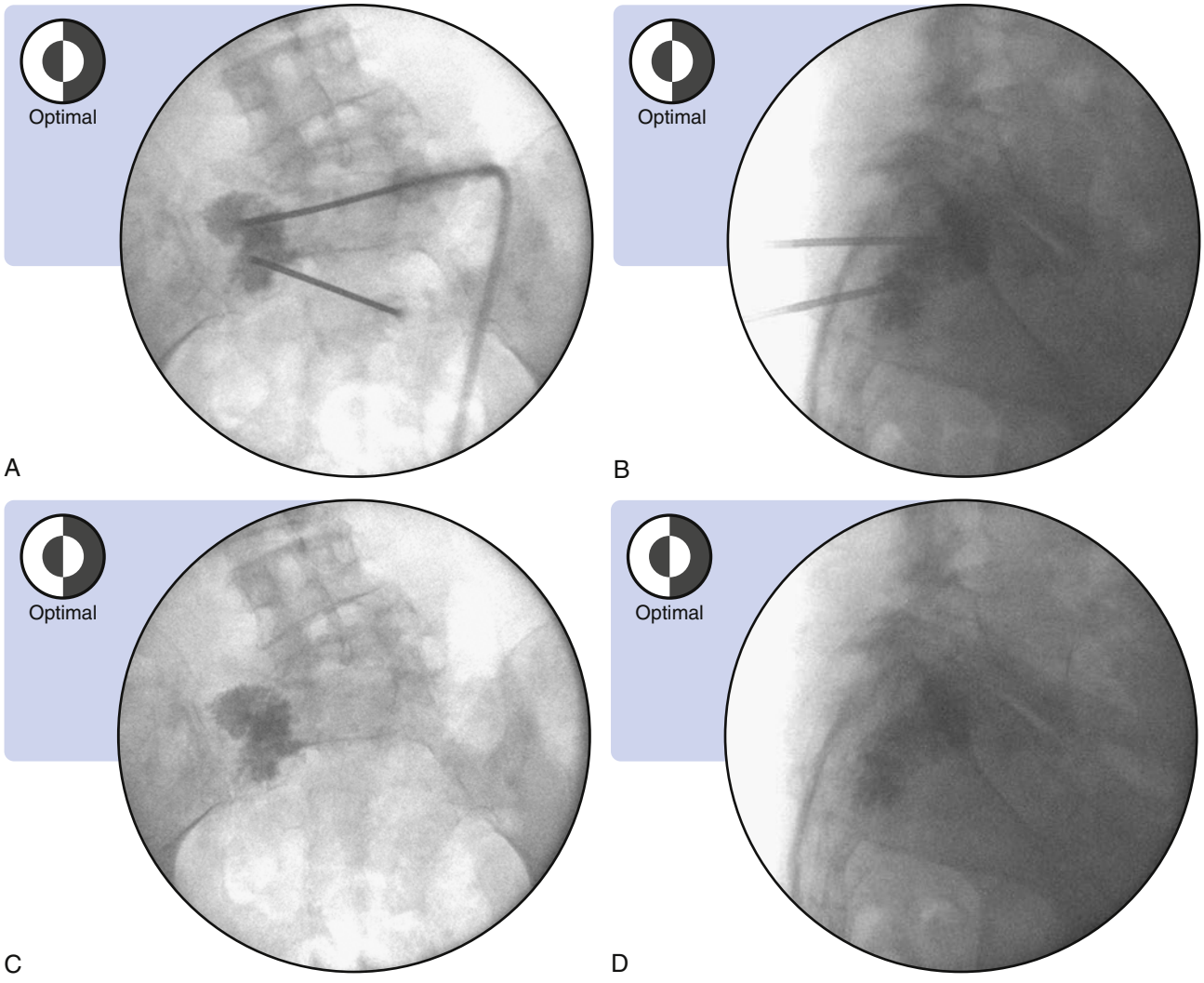


Fig. 9.4. Optimal cement patterns within the sacrum. **A** and **B,** With trocars. **C** and **D,** Without trocars.

Suboptimal Cement Patterns

Suboptimal cement patterns occur when too much cement migrates outside the sacrum (i.e., too medial toward the nerve roots or too anterior into the presacral space). Injecting smaller volumes of approximately 3 to 4 cc of cement per level can reduce the incidence of these suboptimal occurrences (Fig. 9.5). The cement should not traverse the sacral foramen where it can jeopardize, irritate, or compromise the sacral nerve roots (Fig. 9.6).

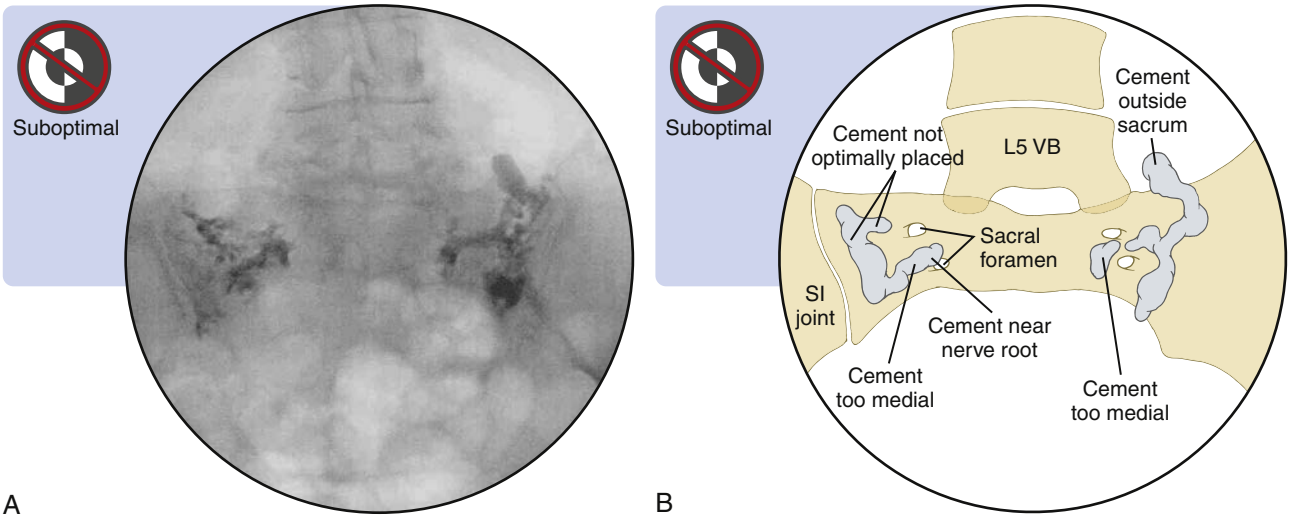


Fig. 9.5. A and **B,** There is a suboptimal cement spread of 3 cc into the bilateral sacral ala. On the patient's right, there is migration of cement outside of the sacrum on the upper lateral aspect of the sacrum, and the cement is also too medial on both sides since it crosses the sacral foramen.

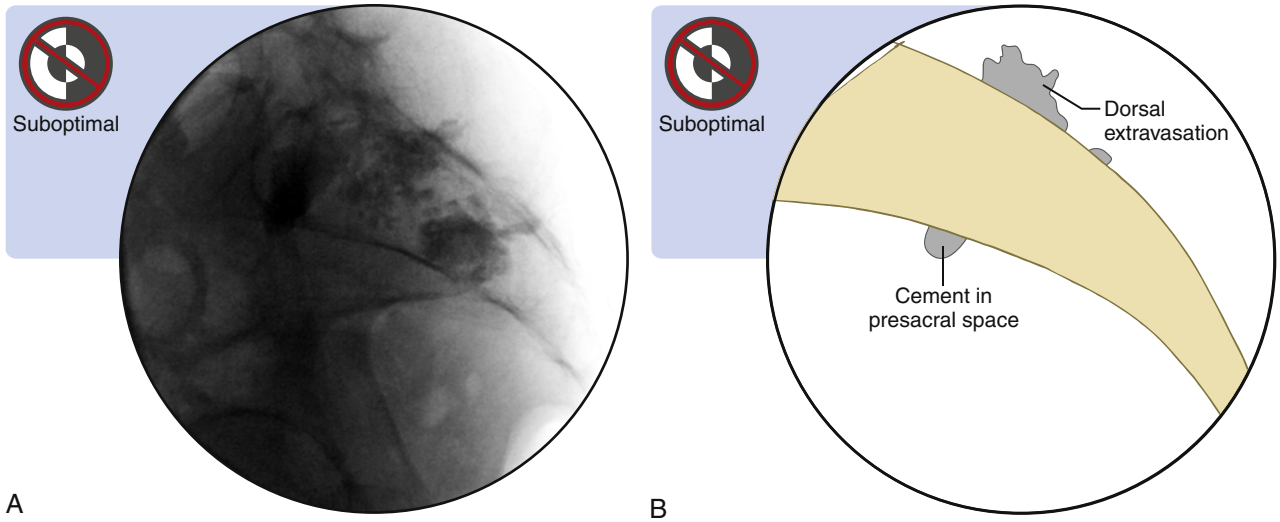


Fig. 9.6. A, Lateral fluoroscopic view demonstrating suboptimal polymethylmethacrylate (PMA) filling after sacroplasty. There is suboptimal spread of the PMA (with contrast) into the presacral space. There is also a small amount of contrast that extends out of the dorsal surface of the sacrum at S2. **B,** Drawing of the fluoroscopic image seen in **A**.

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CHAPTER 10

Sacroiliac Intraarticular Joint Injection

Sacroiliac intraarticular joint (SIJ) injections are relatively safe procedures. While there are no specific structures to avoid, care should be taken to not advance the needle beyond the ventral joint capsule and into the pelvis. Both fluoroscopy-guided and ultrasound-guided approaches will be presented.

The SIJ is an auricular-shaped diarthrodial joint with a joint capsule and synovial fluid. It has a hyaline cartilage on the sacral side and a fibrocartilage on the iliac side.

The exact innervation of the SIJ remains debatable. Some authors have suggested that the joint is innervated both posteriorly and anteriorly; however, others argue that the innervation is exclusively posterior from the lateral branches of the sacral dorsal rami.

The diagnosis of SIJ pain is made by clinical suspicion based on the history and physical examination and can be supported by diagnostic intraarticular injections. To date, there are no reliable imaging studies or physical examination maneuvers to accurately diagnose SIJ dysfunction.

Studies have shown that the actual volume of the joint capsule is not more than 2 ml. Injections of significantly larger volumes will greatly reduce the specificity of this procedure. Because of the potential for capsular defects in the SIJ, the sensitivity and specificity of intraarticular blocks have been questioned. The interosseous or dorsal sacral ligaments, both potential pain generators, are not blocked by intraarticular injections. Studies have shown that while multisite, multidepth sacral lateral branch blocks do not block the intraarticular joint, they are potentially useful tools to evaluate extraarticular SIJ pain.

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Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Suggested Readings

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Dreyfuss P, Michaelsen M, Pauza K, McLarty J, Bogduk N. The value of medical history and physical examination in diagnosing sacroiliac joint pain. *Spine (Phila Pa 1976)*. 1996;21(22):2594–2602.

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CHAPTER 10A

Sacroiliac Intraarticular Joint Injection—Posterior Approach, Inferior Entry: Fluoroscopic Guidance

Leland Berkwits, Gautam Kothari, John P. Batson, III, and Michael B. Furman

Unlike other procedures with orthogonal/multiplanar imaging (i.e., anteroposterior and lateral), the typical views used here are anteroposterior and oblique views that optimize the visualization of the sacroiliac joint (SIJ). The clinical response to SIJ injection is dependent on the intraarticular delivery of medication; therefore, the use of radio-opaque contrast medium is considered essential to confirm intraarticular versus suboptimal flow.[1]

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

The Trajectory View Is Also a Multiplanar View

Tilt the fluoroscope cephalad approximately 10 to 15 degrees to elongate the posterior plane of the joint and improve the target lucency.

- **Oblique the fluoroscope,** starting with 5 to 10 degrees of ipsilateral oblique.
- Under live fluoroscopy, move the C-arm to 10- to 20-degree contralateral oblique. Live fluoroscopy confirms that the more superficial aspect of the joint is visualized as described in Chapter 3, Figure 3.29.
- Watch for the optimal "hyperlucent" region at the inferior portion of the SIJ. C-arm rotation is stopped when the "hyperlucent" region appears.
  - The target needle destination is the inferior aspect of the medial joint space; this corresponds to the posterior aspect of the SIJ. Confirm that the medial joint space is most posterior and superficial under live fluoroscopy
  - Because this is the trajectory view, the needle entry and trajectory should be parallel to the C-arm beam (Fig. 10A.1).

Notes on Positioning in the Trajectory View

- The needle is introduced into the medial aspect of the sacroiliac joint 1 to 2 cm superior to the inferior aspect of the joint.
- The needle is advanced in this position until it is felt to be firmly placed within the joint. If the periosteum is encountered, the needle should be rotated while gentle pressure is used to facilitate further advancement into the joint.

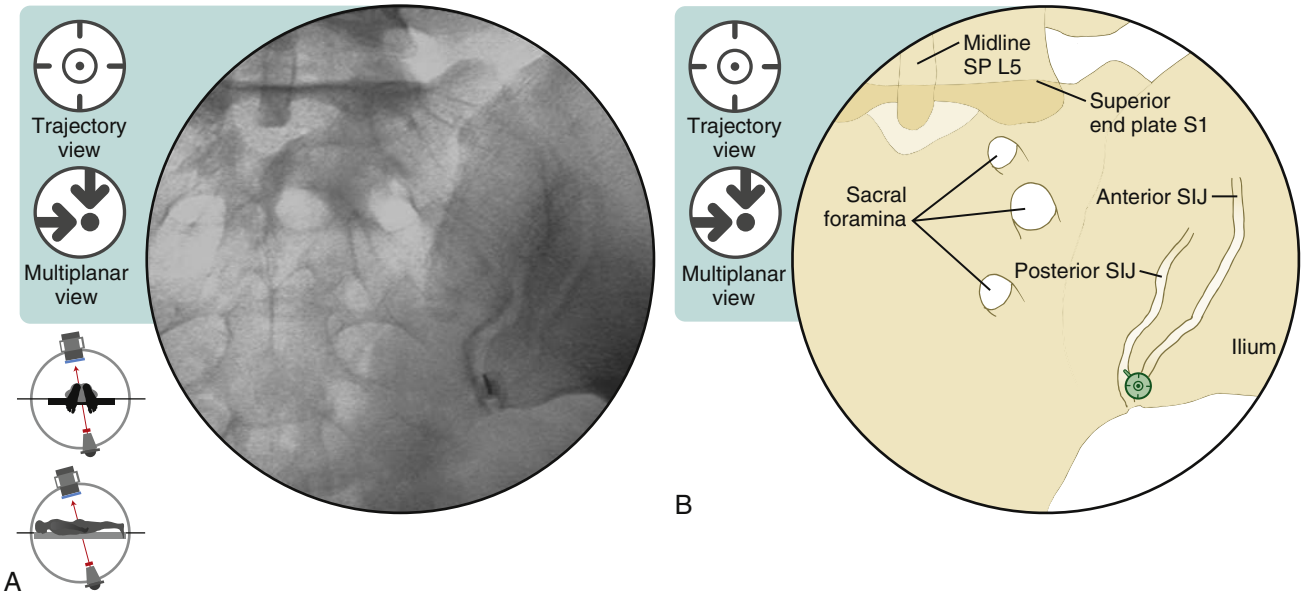

Fig. 10A.1. A, Fluoroscopic image of the trajectory view with the needle in position at the medial aspect of the inferior sacroiliac joint. **B,** Radiopaque structures, trajectory view.

We recommend observing the safety considerations described in other views. There are no consistent safety considerations in this view.

Optimal Needle Position in Multiplanar Imaging (Figs. 10A.2 and 10A.3)

The Trajectory View Is Also a Multiplanar View

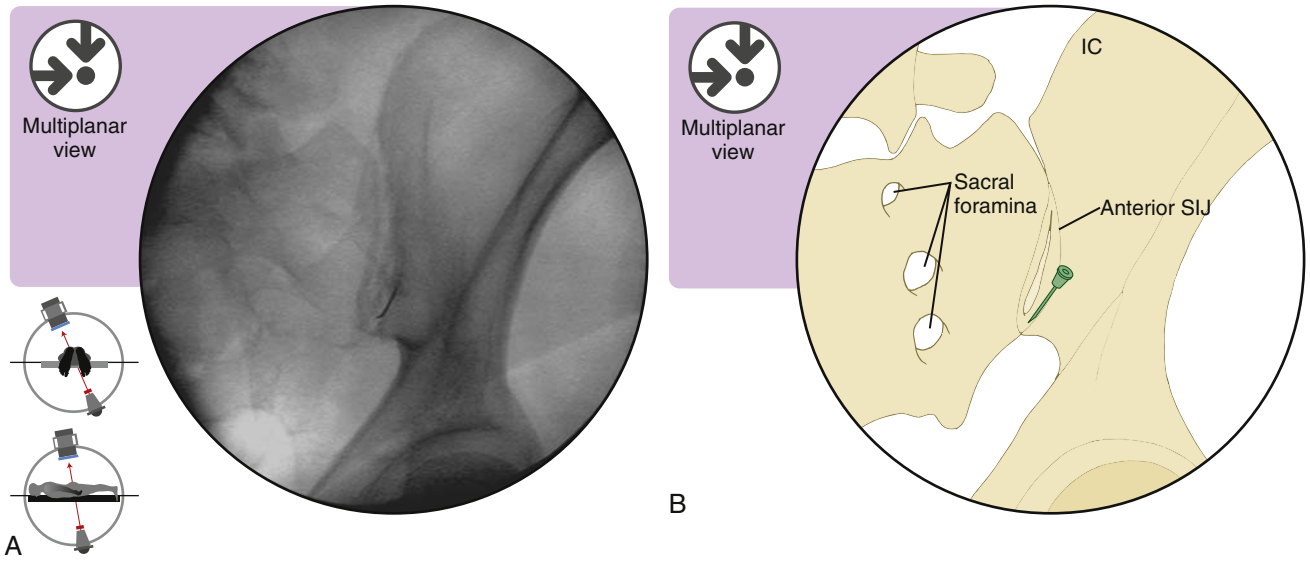

Fig. 10A.2. A, Fluoroscopic contralateral oblique view. **B,** Radiopaque structures, contralateral oblique.

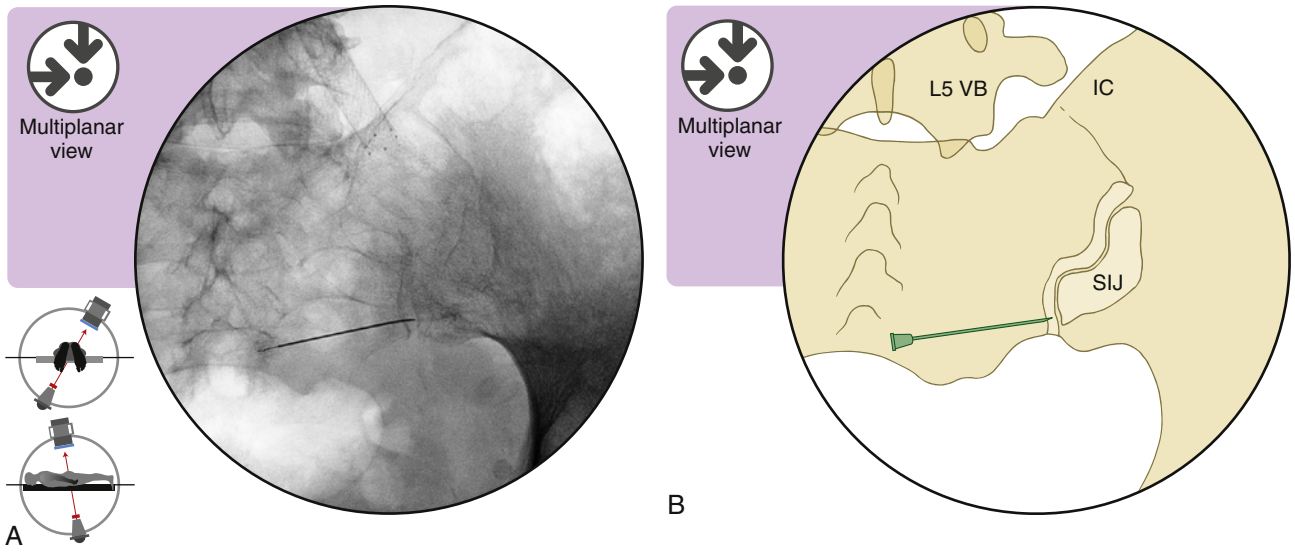

Fig. 10A.3. A, Fluoroscopic ipsilateral oblique view facilitates the visualization of the needle as it approaches the sacroiliac joint. The needle has entered the joint when it lies between the medial and lateral joint line. **B,** Radiopaque structures, ipsilateral oblique.

Notes on Multiplanar Imaging

- Multiplanar imaging in the case of sacroiliac intraarticular joint injections is helpful while driving the needle into the joint to assess proper depth. The C-arm is positioned approximately 15-degree ipsilateral oblique to visualize the needle's approach to the joint line.
- In the ipsilateral oblique view, the needle enters the joint when it is advanced to the space between the medial and lateral joint margins.
- Further confirmation of intraarticular needle placement includes the movement of the C-arm ipsilaterally and contralaterally to ensure that needle placement within the joint space can be seen with different views.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 10A.4)

Once the needle is confirmed to be in the optimal position with multiplanar oblique imaging, a lateral image is obtained.

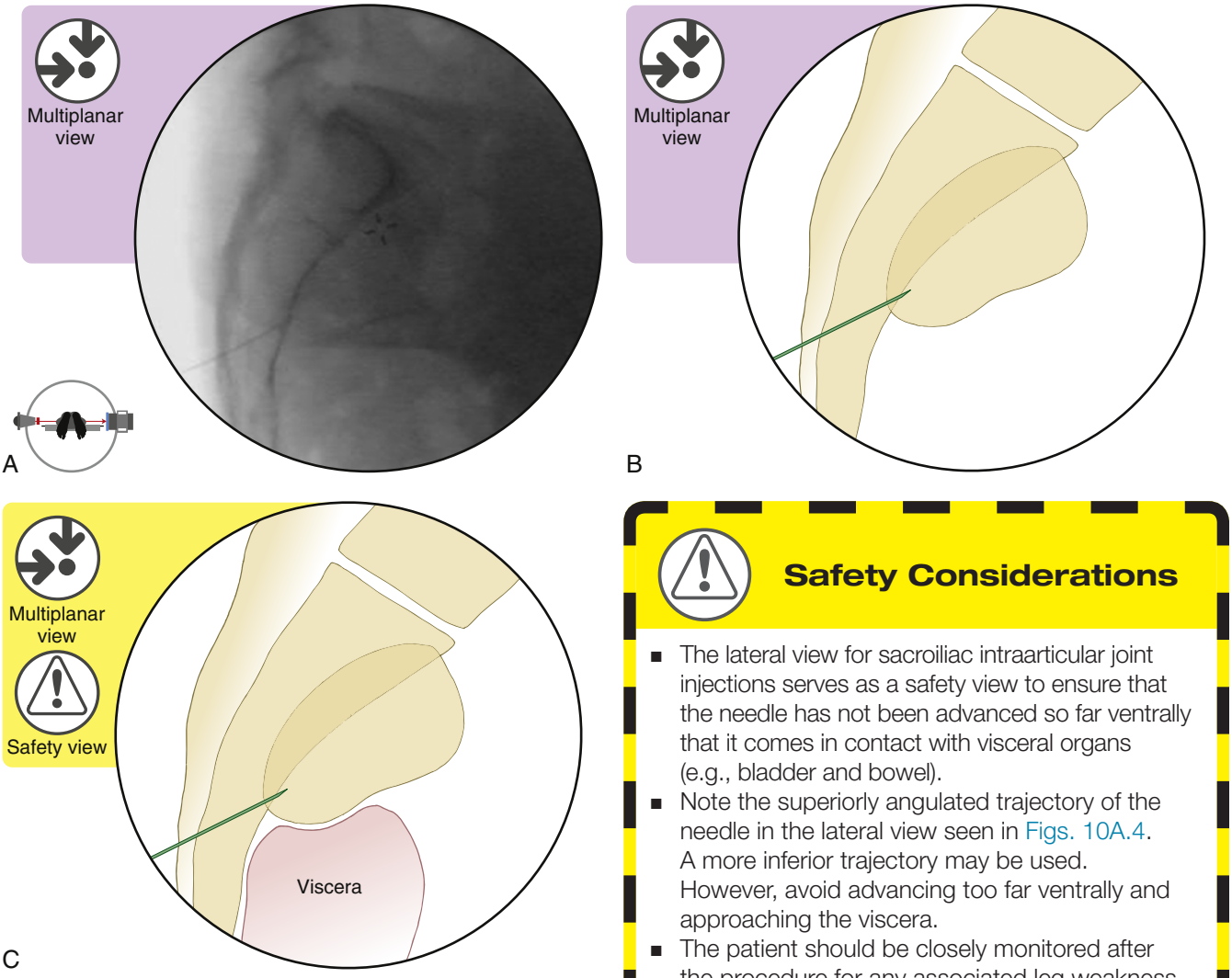

Fig. 10A.4. A, Fluoroscopic lateral view with an ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Safety Considerations

- The lateral view for sacroiliac intraarticular joint injections serves as a safety view to ensure that the needle has not been advanced so far ventrally that it comes in contact with visceral organs (e.g., bladder and bowel).
- Note the superiorly angulated trajectory of the needle in the lateral view seen in Figs. 10A.4. A more inferior trajectory may be used. However, avoid advancing too far ventrally and approaching the viscera.
- The patient should be closely monitored after the procedure for any associated leg weakness or instability. Even with optimal flow patterns and appropriate injection volumes, some of the steroid/anesthetic may breach the joint capsule ventrally to the sacral plexus, dorsally to the sacral foramina, superiorly to L5, or inferiorly to the sciatic nerve.[2]

AXIAL MAGNETIC RESONANCE IMAGING OF THE SIJ

The axial magnetic resonance imaging (MRI) of the pelvis seen in Fig. 10A.5 demonstrates the medial aspect of the SIJ, which corresponds to the posterior aspect of the joint, which is the most superficial and accesible portion of the SIJ in a prone patient. Therefore, it is imperative that the medial aspect of the joint be targeted to ensure optimal joint access.

Fig. 10A.5. The axial view of the pelvis shows the typical sacroiliac intraarticular (SI) joint orientation with the patient in the prone position. Note that the joint is oriented in the contralateral oblique plane. The medial aspect of the joint *(arrows)* is dorsal to the lateral aspect of the joint, and is, therefore, more superficial and accessible in a prone patent.

Optimal Images (Figs. 10A.6, 10A.7, and 10A.8)

Optimal Image

- The ideal contrast flow should be visualized outlining the medial and lateral aspects of the sacroiliac joint.
- If initial resistance to injection is encountered when injecting the contrast, rotation of the needle (i.e., bevel) while maintaining gentle pressure on the syringe plunger can facilitate the flow of the contrast.
- If resistance to the injection is encountered, despite needle rotation, flow may be facilitated by withdrawing or advancing the needle 1 to 2 mm.

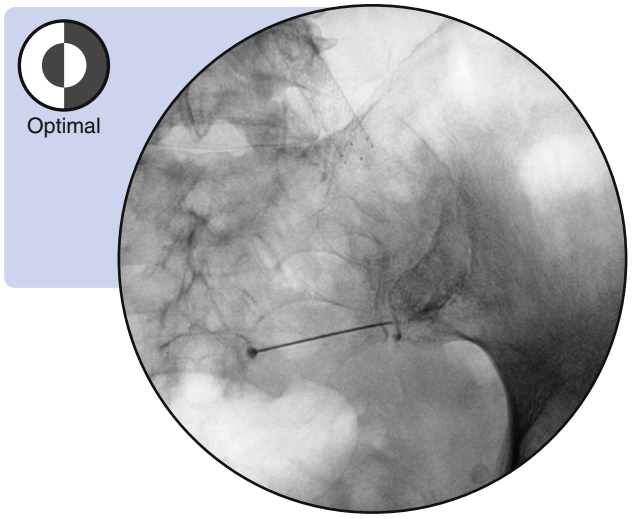

Fig. 10A.6. Ipsilateral oblique image of the sacroiliac joint with 0.5 cc of contrast, optimal.

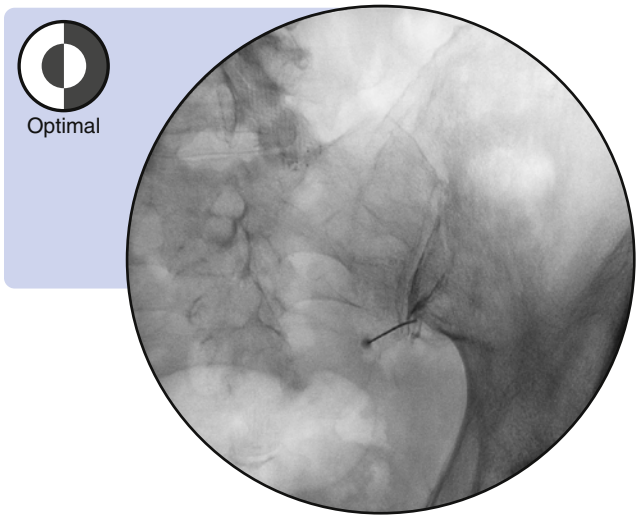

Fig. 10A.7. Anteroposterior (AP) image of sacroiliac joint depicted in Fig. 13.5, with 0.5 cc of contrast, optimal. Often a thin line of contrast flow can be seen throughout the entire joint.

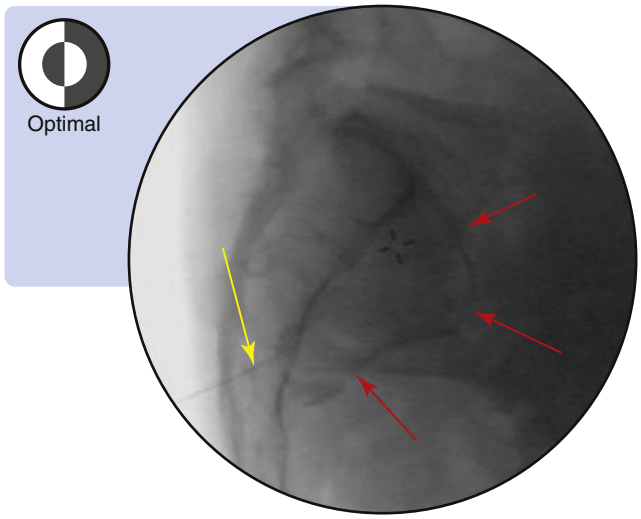

Fig. 10A.8. Lateral image of the needle *(yellow arrow)* in the sacroiliac joint with 0.5 cc of contrast *(red arrows)*, optimal.

Suboptimal Images (Figs. 10A.9, 10A.10, and 10A.11)

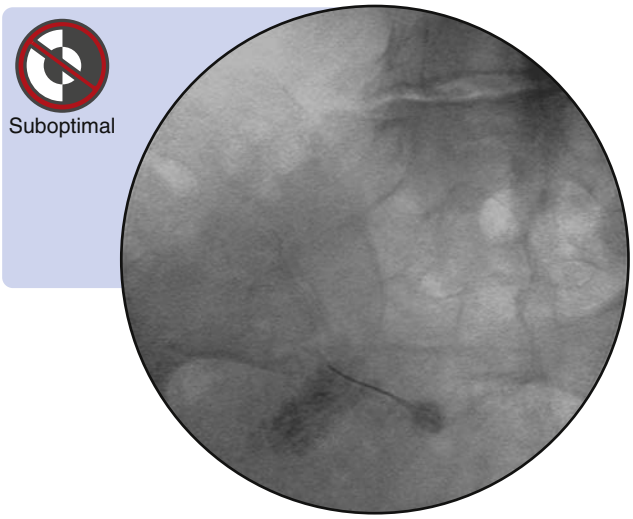

Fig. 10A.9. Suboptimal sacroiliac intraarticular joint injection. Contrast is seen pooling outside the joint space.

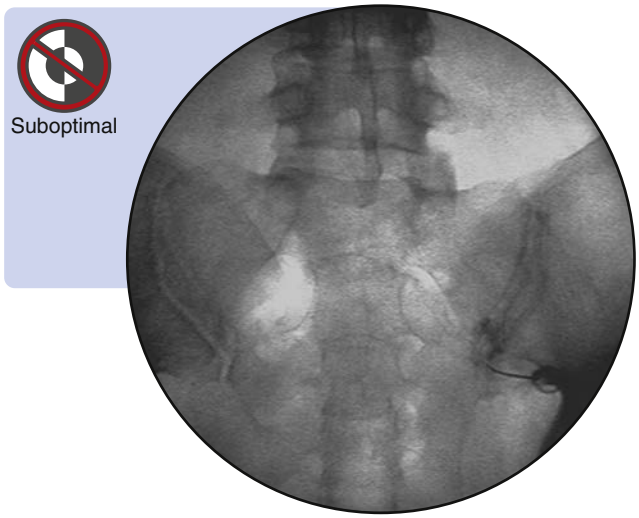

Fig. 10A.10. Suboptimal sacroiliac intraarticular joint injection. Contrast is not seen within the joint space or outlining the mediolateral aspect of the joint.

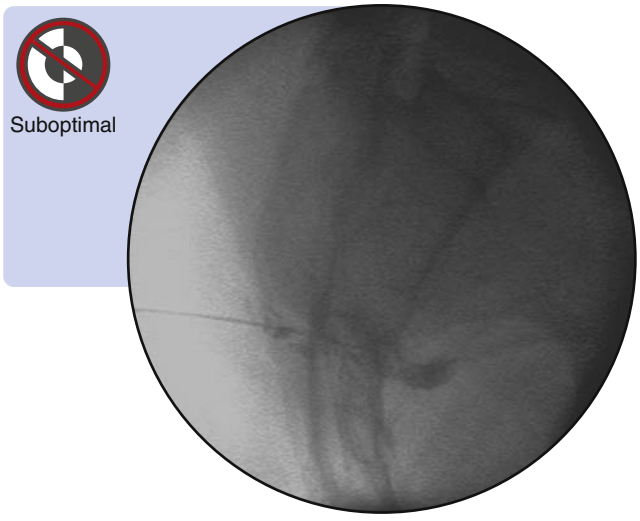

Fig. 10A.11. Suboptimal sacroiliac intraarticular joint injection in the lateral view. The contrast extends out of the joint ventrally and dorsally.

References

1. Bogduk N, ed. *Sacroiliac Joint Access. Practice Guidelines for Spinal Diagnostic and Treatment Procedures*, 2 ed. San Francisco, CA: International Spine Intervention Society; 2014;533–555.
2. Fortin JD, Washington WJ, Falco JF. Three pathways between the sacroiliac joint and neural structures. *AJNR Am J Neuroradiol*. 1999;20(8):1429–1434.

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CHAPTER 10B

Sacroiliac Intraarticular Joint Injection: Ultrasound Guidance

Amir Tahaei, Lius Baez-Cabrera, Paul S. Lin, and Michael B. Furman

An in-plane ultrasound-guided injection technique will be presented since it allows for continuous needle tip visualization. We recommend a combined ultrasound-fluoroscopy hybrid procedure utilizing ultrasound guided-needle placement followed by fluoroscopically visualized radiopaque contrast injection confirming nonvascular, intraarticular contrast flow.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 10B.1)

- Have the patient in the prone position, and place pillows under the pelvis to help with anatomic visualization.
- Ultrasound image on the opposite side of interventionist and in line with the transducer (Fig. 10B.1D).
- Utilize a curvilinear transducer for patients with more posterior adipose tissue and a gel stand off and linear transducer for patients with limited adipose tissue.
- A slight bend in the needle tip may help facilitate joint entry.
- Place the transducer over the posterior superior iliac spine **(PSIS)** and translate **medially** to identify the S1 foramen (see Fig. 4.33).
- Then, sweep the transducer **inferiorly** from the PSIS to identify the inferior SIJ **recess/capsule**, which is **lateral** to the **S2 foramen** (Fig. 10B.1A, B).
- Insert the needle from **medial to lateral** in-plane with care to avoid the S2 foramen.
- The placement in the SIJ space is confirmed using contrast-enhanced real-time fluoroscopy (Fig. 10B.2).

Fig. 10B.1. A, Suggested room, interventionalist, transducer, and ultrasound unit setup for injection.

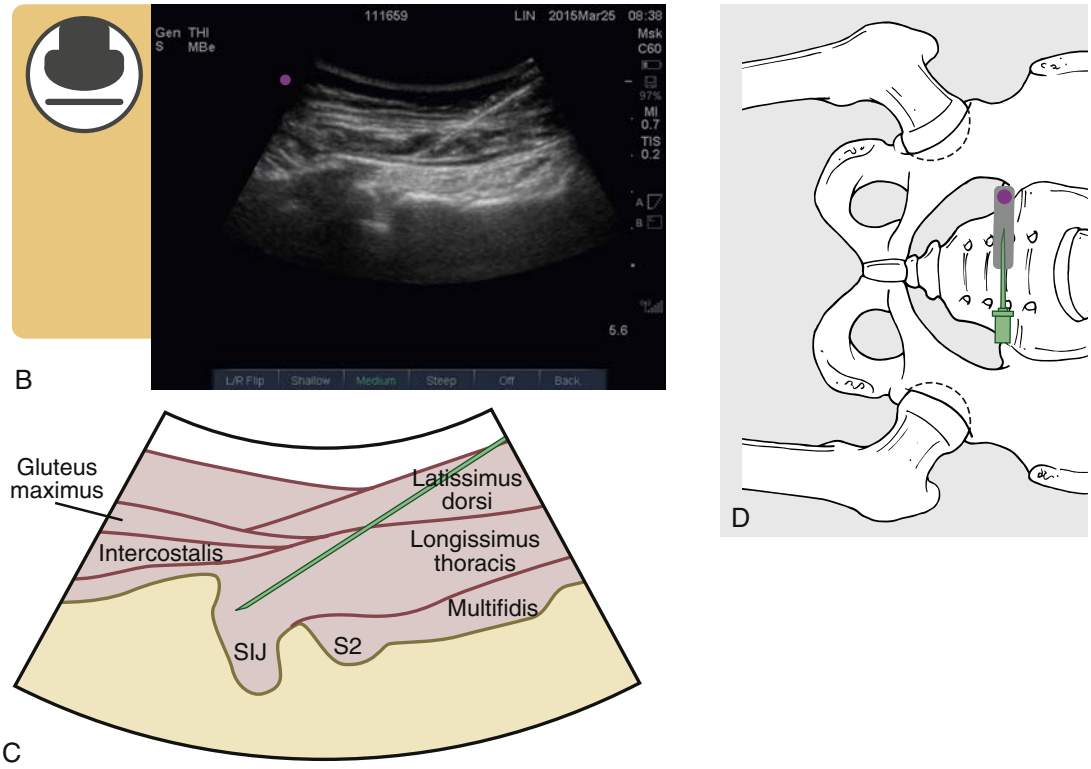


Fig. 10B.1. B, Ultrasound image of bony landmark (in white) of sacroiliac intraarticular joint (SIJ) needle placement. **C,** A drawing showing the anatomy corresponding to Part B, including the landmarks at SI level (SI joint recess/capsule and S2 foramen) with a needle. **D,** Proper placement of an ultrasound transducer on the skeleton.

Optimal Image (Fig. 10B.2)

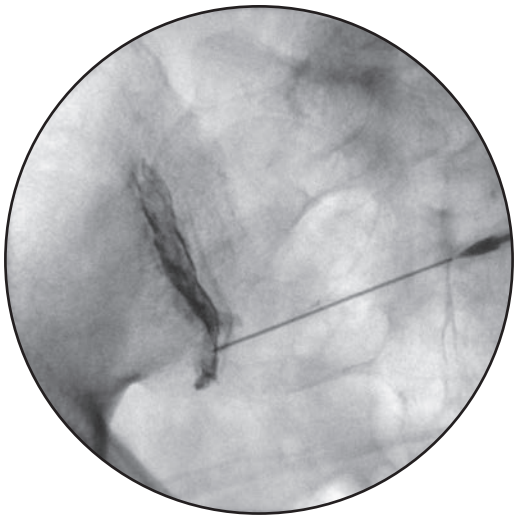


Fig. 10B.2. Fluoro image of optimal contrast flow (arthrogram) within the sacroiliac intraarticular joint (SIJ) after ultrasound (US)-guided SIJ injection. The contrast should spread cephalad to PSIS. However, this flow may vary. Note that the US guided needle trajectory starts much more medially than that of a fluoroscopically guided one. Note that the US guided needle trajectory starts much more medially than that of a fluoroscopically guided one.

In-Plane Technique Safety Considerations

- To avoid visceral injury do not advance the needle too ventral and/or through the bone in patients with osteoporosis.
- Avoid S1 or S2 transforaminal inadvertent injections.

There is no recommended out-of-plane (multiplanar) view available for this procedure.

CHAPTER 11

S1 Transforaminal Epidural Steroid Injection

Jonathan B. Stone, Leland Berkwits, Luis Baez-Cabrera, and Michael B. Furman

The transforaminal epidural steroid injection delivers injectate to the ventral epidural space, the posterior anulus, and the ventral aspect of the nerve root sleeve.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

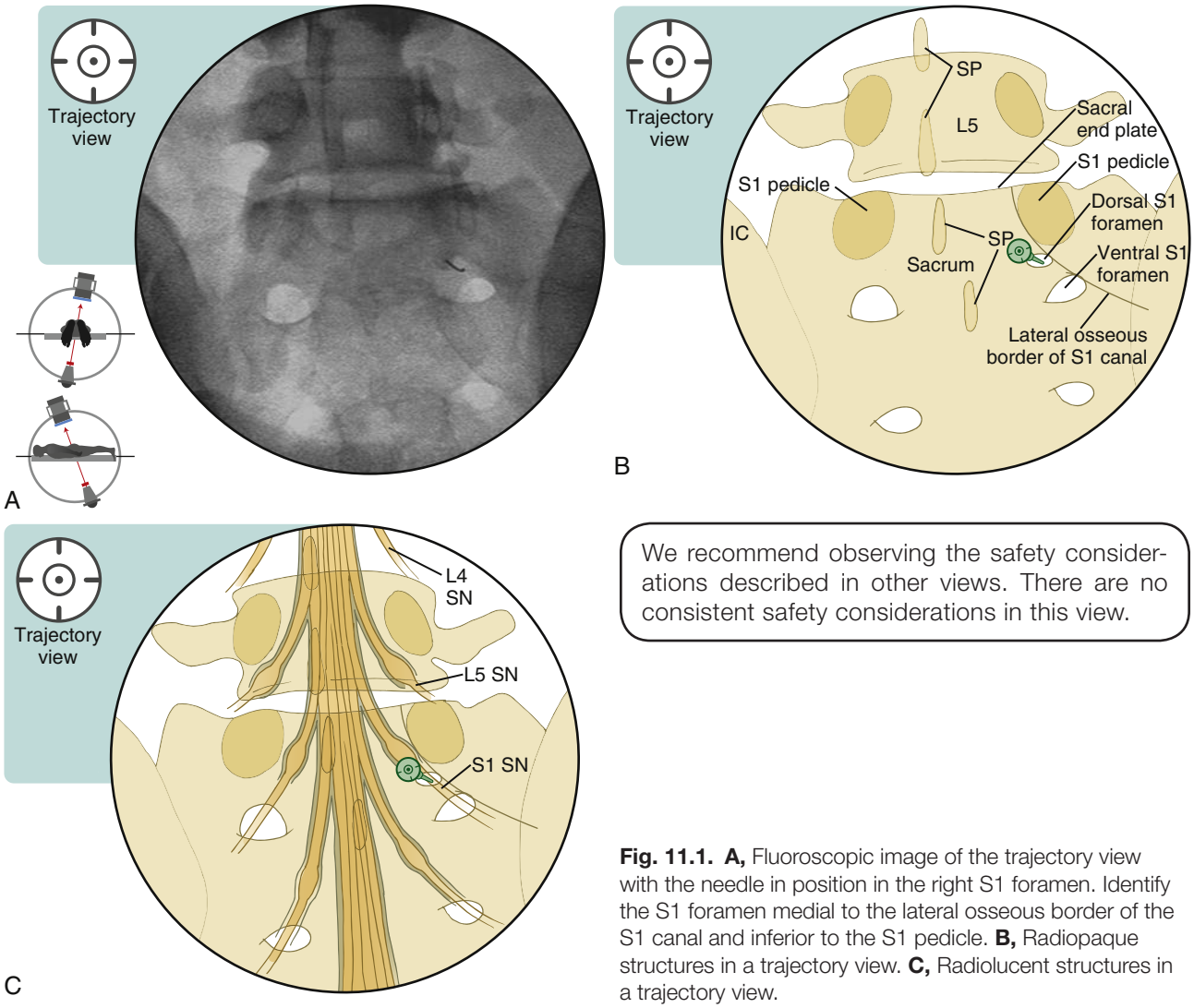
Confirm the level (with the anteroposterior view) before obtaining the trajectory view (see Chapter 1).
Tilt the fluoroscope cephalad (Fig. 11.1).

- Line up the superior S1 end plate by tilting the beam cephalad. The goal is to optimize visualization of the dorsal S1 foramen. Squaring off the superior S1 end plate provides an initial starting point for optimizing visualization.

Oblique the fluoroscope ipsilaterally.

- The target needle destination is the dorsal S1 foramen, just inferior to the S1 pedicle.
- The dorsal S1 foramen is better visualized with a slight ipsilateral oblique view. Optimal visualization is dependent on anatomy, and, in some individuals, it may be achieved without using the oblique view. Repositioning the fluoroscope to a less cephalad tilt may help in visualizing the dorsal S1 foramen.
- Aim to be in the superolateral aspect of the posterior S1 foramen because the nerve runs inferolateral.
- The ventral S1 foramen may be in line with the dorsal S2 foramen as a result of the cephalad tilt of the fluoroscope beam.

Place the needle coaxial to the fluoroscopic beam.



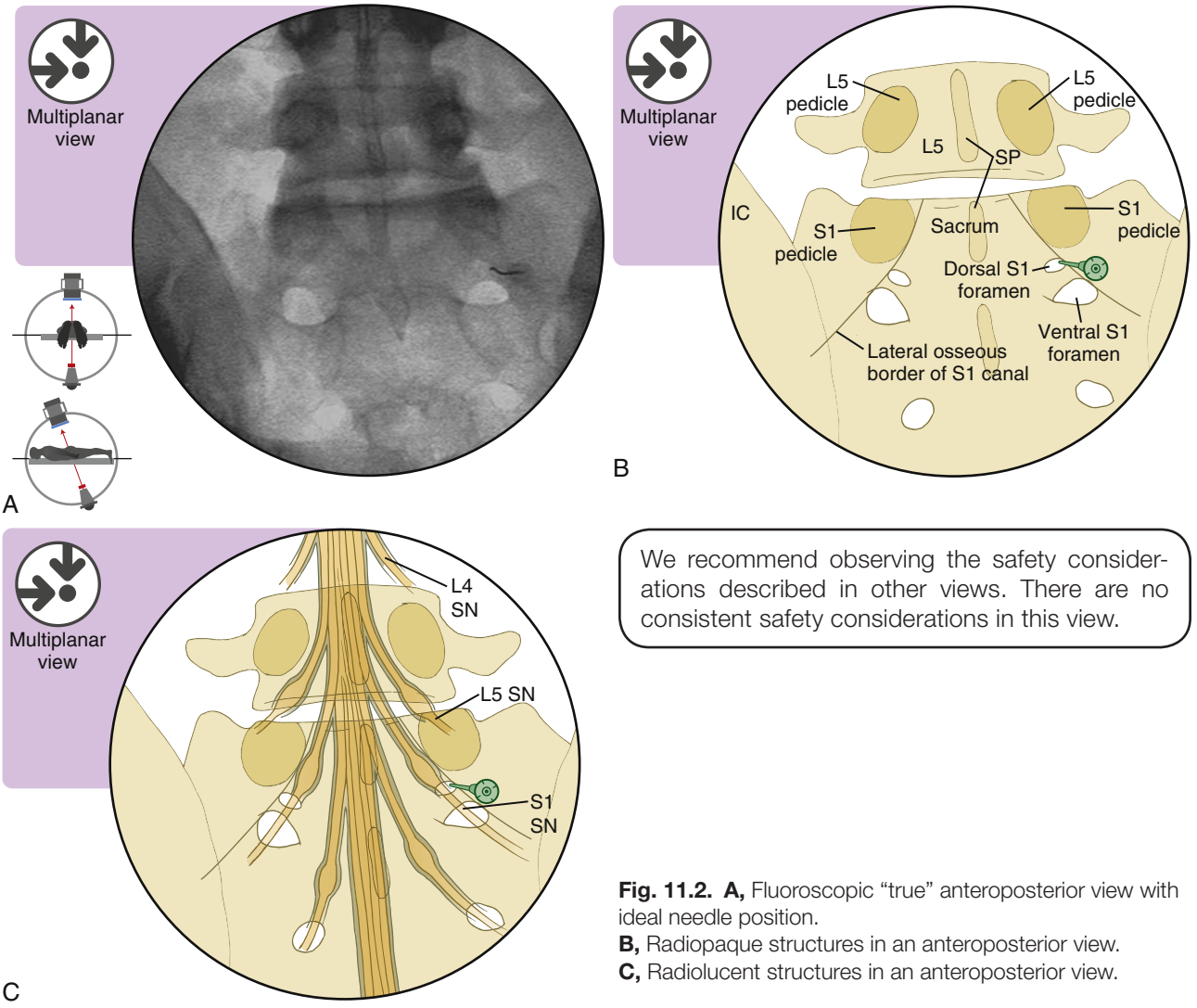
We recommend observing the safety considerations described in other views. There are no consistent safety considerations in this view.

Fig. 11.1. A, Fluoroscopic image of the trajectory view with the needle in position in the right S1 foramen. Identify the S1 foramen medial to the lateral osseous border of the S1 canal and inferior to the S1 pedicle. **B,** Radiopaque structures in a trajectory view. **C,** Radiolucent structures in a trajectory view.

Optimal Needle Position in Multiplanar Imaging

OPTIMAL NEEDLE POSITIONING FOR THE ANTEROPOSTERIOR VIEW (FIG. 11.2)

After needle placement in the trajectory view, oblique the C-arm into a fluoroscopic "true" AP view

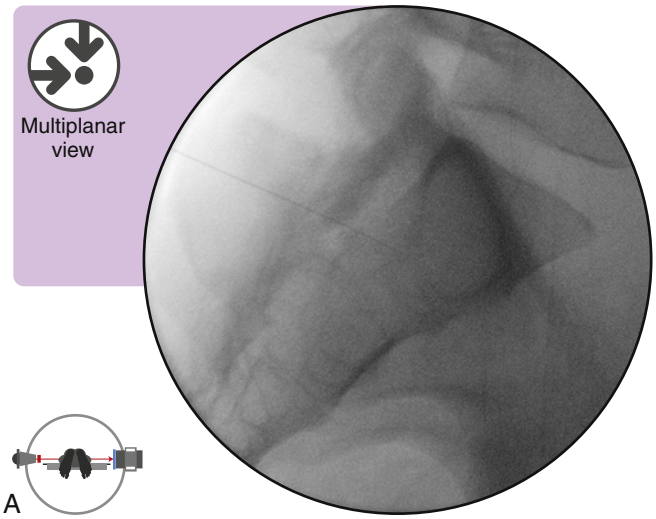


We recommend observing the safety considerations described in other views. There are no consistent safety considerations in this view.

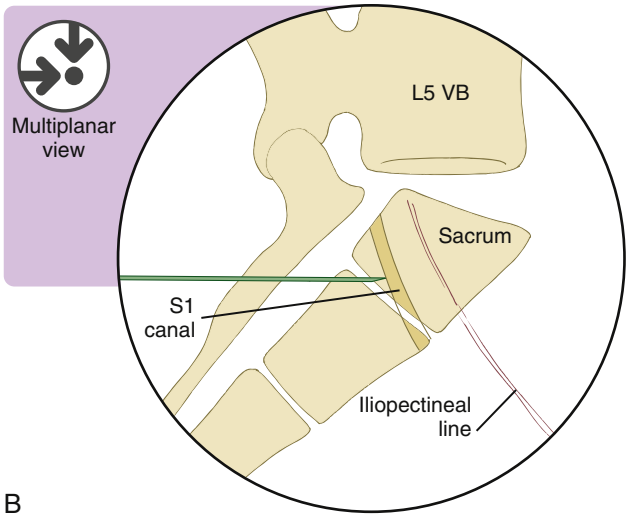
Fig. 11.2. A, Fluoroscopic "true" anteroposterior view with ideal needle position.
B, Radiopaque structures in an anteroposterior view.
C, Radiolucent structures in an anteroposterior view.

OPTIMAL NEEDLE POSITIONING FOR THE LATERAL VIEW (FIG. 11.3)

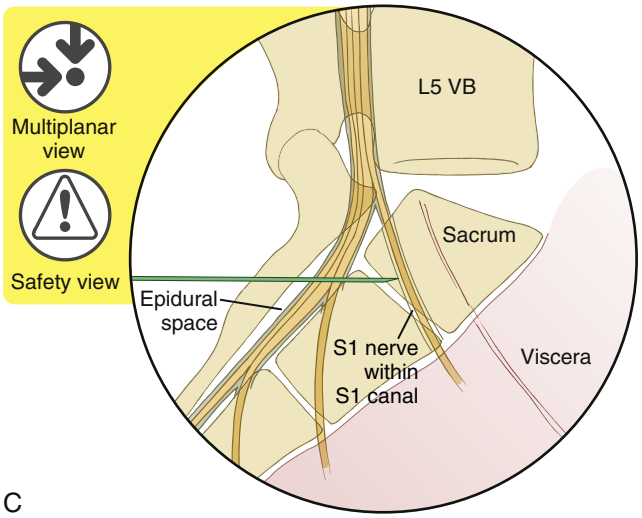
- When the needle is positioned in a trajectory view toward the dorsal S1 foramen and confirmed with the anteroposterior view, then a lateral image is obtained. This is the true "safety view," which is used to verify the needle depth.
- The C-arm should be oriented to obtain a true lateral view (see Chapter 3).
- In the ideal lateral view, the iliopectineal line is a single straight line rather than two separate lines. The use of wig-wag of the fluoroscope allows this view to be optimized (see Chapter 3).
- "Walking off" sacral periosteum around the dorsal S1 foramen into the foramen also allows estimating the needle tip depth. Confirm needle tip location relative to the sacral canal with a lateral image.



A



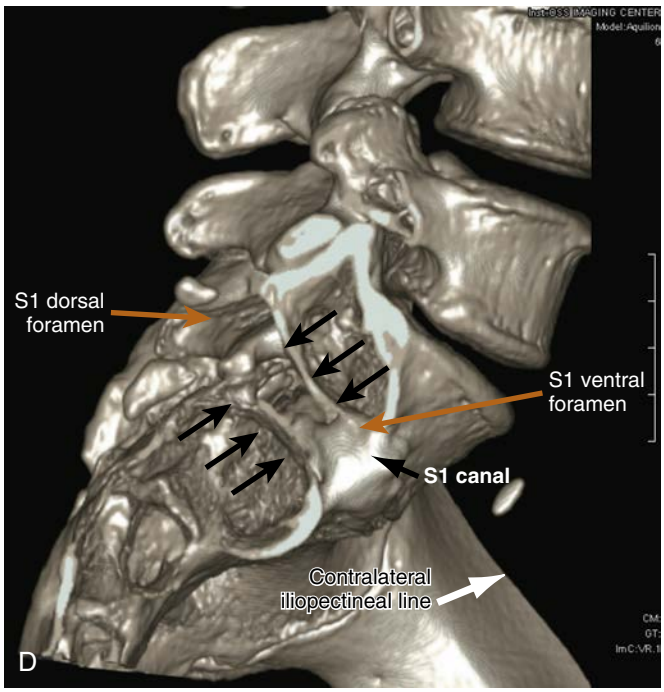
B



C

Lateral View Safety Considerations

- The lateral view allows one to verify the needle depth to make sure that the needle tip is not too far ventral. The needle should not be advanced to the floor of the sacral canal. It should not exit the ventral S1 foramen. Avoid the viscera ventral to the sacrum.
- Target depth should be just beyond the ventral epidural space but not up against the periosteum of the sacral canal floor.



D

Fig. 11.3. A, Fluoroscopic lateral view with the ideal needle position for an S1 transforaminal injection. **B,** Radiopaque structures in a lateral view. The radiopaque curved structure located within the ventral aspect of the sacral canal represents the osseous floor of the S1 root canal. **C,** Radiolucent structures in a lateral view. **D,** Three-dimensional reconstruction computed tomography scan with a sagittal cut through the sacrum to demonstrate the ipsilateral S1 canal *(black arows)* and the contralateral iliopectineal line.

Optimal Images (Figs. 11.4, 11.5, and 11.6)

Optimal Image

- Ideal contrast flow should outline the spinal nerve and nerve root sheath and then flow into the epidural space medial to the S1 pedicle and to the suspected site of pathology.
- Confirm nonvascular injection under live-contrast injection.
- Occasionally, blood is noted to ooze back into the needle hub, despite nonvascular contrast. In these cases, we assume a vascular injection has occurred and act accordingly.

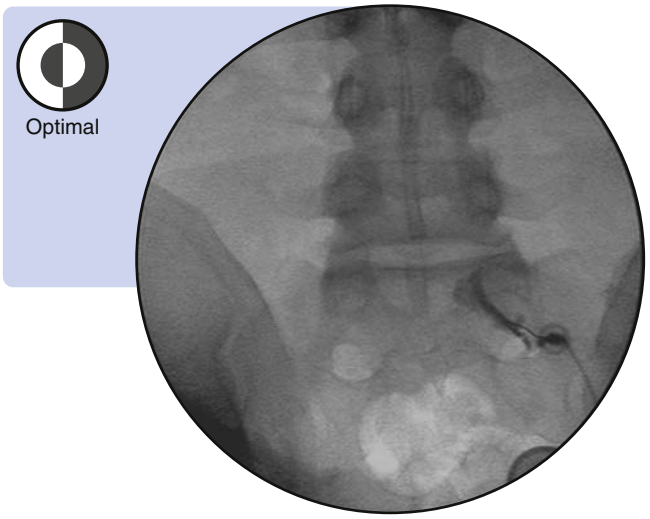


Fig. 11.4. Anteroposterior fluoroscopic image of the right S1 transforaminal injection with 0.5 cc of contrast solution.

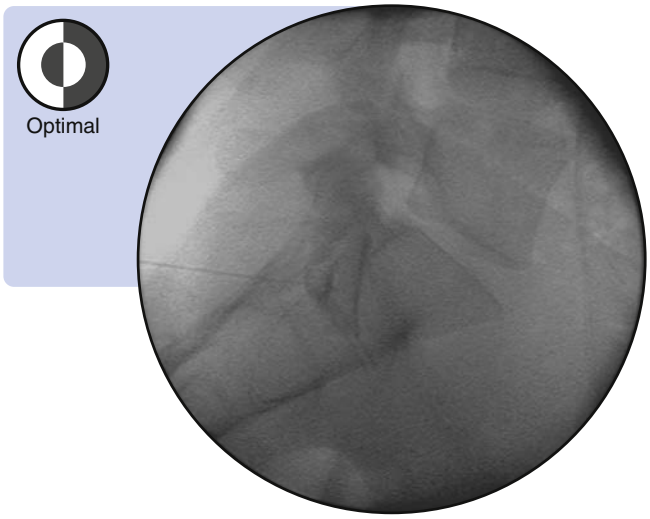


Fig. 11.5. Lateral fluoroscopic image of the right S1 transforaminal injection with 0.5 cc of contrast solution.

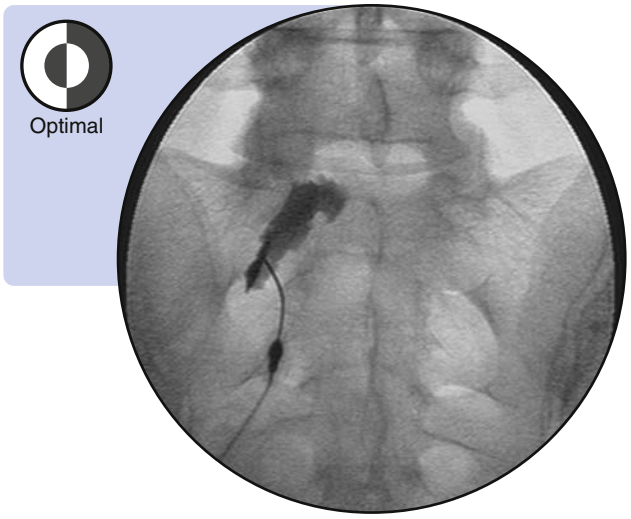


Fig. 11.6. Left S1 transforaminal epidural steroid injection with 2.5 cc of contrast solution.

Suboptimal Images (Figs. 11.7 and 11.8)

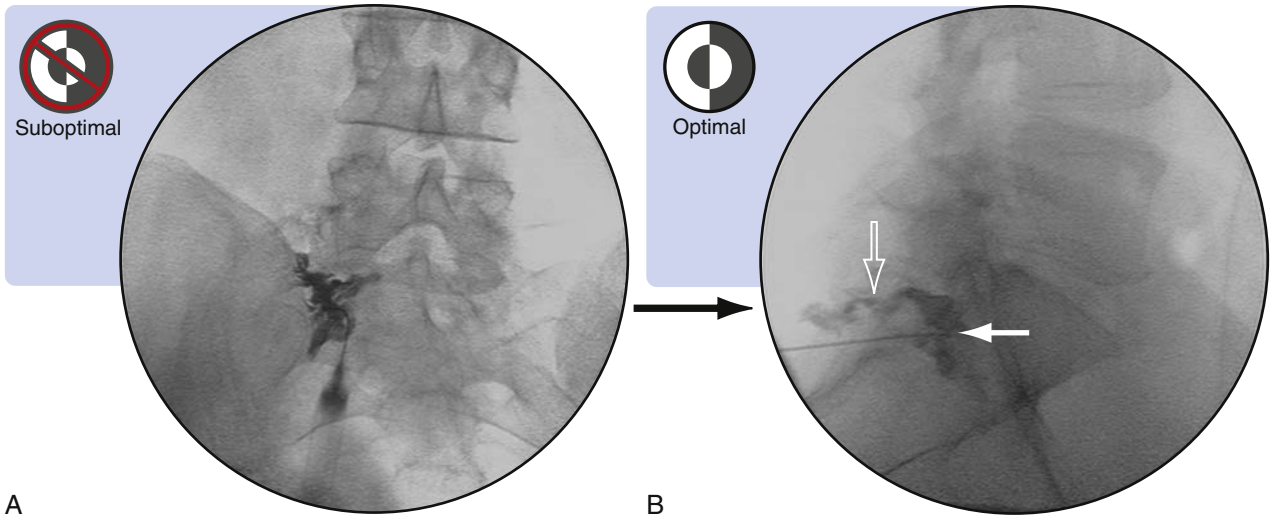


Fig. 11.7. A, Anteroposterior fluoroscopic image of the left S1 transforaminal epidural steroid injection with a nonideal contrast flow. This needle is likely positioned too dorsal; it needs to be advanced more ventral under a lateral view. **B,** In this lateral view, the needle was repositioned more ventrally, and a more optimal contrast flow pattern was obtained *(closed arrow)*. The *open arrow* points to the initial suboptimal contrast in the dorsal soft tissues.

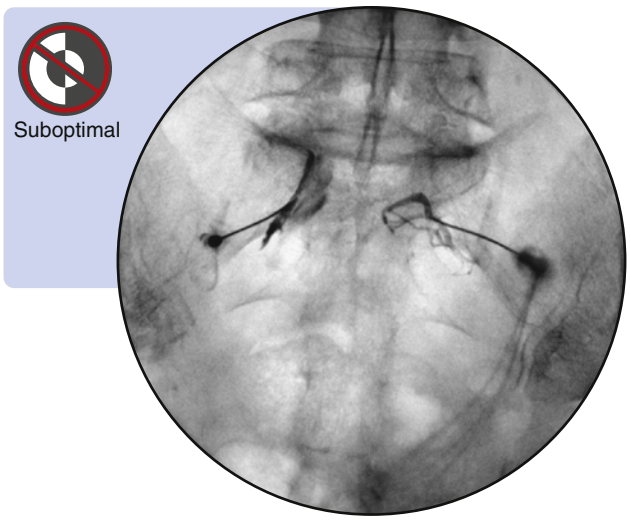


Fig. 11.8. This fluoroscopic image demonstrates optimal flow along the left S1 level and vascular flow at the right S1 level. Although the image is static, when this is observed under live fluoroscopy, the contrast rapidly dissipates. A lack of flash in the needle hub or the absence of blood return on aspiration does not confirm the absence of a vascular flow (Furman et al., 2000).

References

1. Derby R, Kine G, Saal JA, et al. Response to steroid and duration of radicular pain as predictors of surgical outcome. *Spine (Phila Pa 1976)*. 1992;17(6):S176–S183.
2. Derby R, Bogduk N, Kine G. Precision percutaneous blocking procedures for localization of spinal pain. Part 2. The lumbar neuraxial compartment. *Pain Digest*. 1993;3:175–188.
3. Furman MB, O'Brien EM, Zgleszewski TM. Incidence of intravascular penetration in transforaminal lumbosacral epidural steroid injections. *Spine (Phila Pa 1976)*. 2000;25(20):2628–2632.
4. Bogduk N, ed. *International Spinal Intervention Society practice guidelines for spinal diagnostic and treatment procedures: lumbar spinal nerve blocks*. San Francisco, CA: International Spine Intervention Society; 2004.

Suggested Reading

Furman MB, Butler SP, Kim RE, Mehta AR, Simon JI, Patel R, Lee TS, Reeves RS. Injectate volumes needed to reach specific landmarks in S1 transforaminal epidural injections. *Pain Med*. 2012 Oct;13(10):1265–1274.

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CHAPTER 12

Lumbar Interlaminar Epidural Steroid Injection: Paramedian Approach

Amir S. Tahaei, Scott J. Davidoff, and Michael B. Furman

Lumbar interlaminar epidural injections are commonly performed for a variety of spinal pain disorders. They are specifically indicated for radicular symptoms with or without axial pain experienced because of a lumbosacral etiology. Because the injectate disperses over a larger area with interlaminar epidural injection than with transforaminal injection, this type of injection is typically used for bilateral or multilevel symptoms.

With the approach described here, the needle is placed with the use of a trajectory view and advanced with the use of multiplanar imaging, with emphasis on safely using the contralateral oblique (CLO) and/or lateral view to confirm the depth by visualizing the ventral interlaminar line (VILL) or spinolaminar line, respectively.

The CLO view is preferable to the lateral view in advancing the needle to gain access to the interlaminar space. The role of the CLO view is especially preferable to the lateral view, as discussed in Chapter 3.

Because depth is assessed with one of these "safety views," it is not necessary to use the "step-off lamina" technique. Once the needle tip location is confirmed with multiplanar imaging, the epidural space is accessed by advancing the needle through the ligamentum flavum using the classic loss-of-resistance technique. The loss-of-resistance technique requires the presence of the ligamentum flavum to identify the epidural space. The postlaminectomy absence of the ligamentum flavum would prevent accurate localization of the epidural space and increase the likelihood of an intrathecal injection. Also, the presence of spondylolisthesis and severe central spinal stenosis will increase the risk of intrathecal injection. In these settings, an alternate route of delivery of the injectate should be considered (transforaminal, caudal with/without catheter, or interlaminar at a nonsurgical level above or below the requested injection level).

For patients with predominantly unilateral or asymmetric pain, the injectate is targeted toward the symptomatic side. In the case of a unilateral dye pattern, in a patient with bilateral symptoms, consider adjusting the needle tip position to the other side as well for bilateral epidural space injectate coverage.

We include a discussion, table, and examples of epidural, subdural, and intrathecal flow to help delineate them. More flow patterns are also available in the Myelography chapter (14).

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

Confirm the level (with the anteroposterior view).

The image intensifier is tilted caudally to open up the target interlaminar space and facilitate easier entry between two adjacent laminae (Fig. 12.1).

The C-arm is then obliqued approximately 5 to 10 degrees toward the more symptomatic side (i.e., the left side, in this case). This angle is used for entry, and the needle should be aimed between the laminae on either side of the space between the superior and inferior spinous processes (i.e., midline).

Because this is the trajectory view, **the needle should be placed parallel to the fluoroscopic beam.**

Notes on Positioning in the Trajectory View

- With this approach, the needle tip is placed between the laminae instead of "walking off" the lamina.
- The caudal tilt is used to optimally open up the interlaminar space (and not to optimally line up the end plates). Caudal tilt also establishes an ideal trajectory angle to enter between the adjacent lamina.

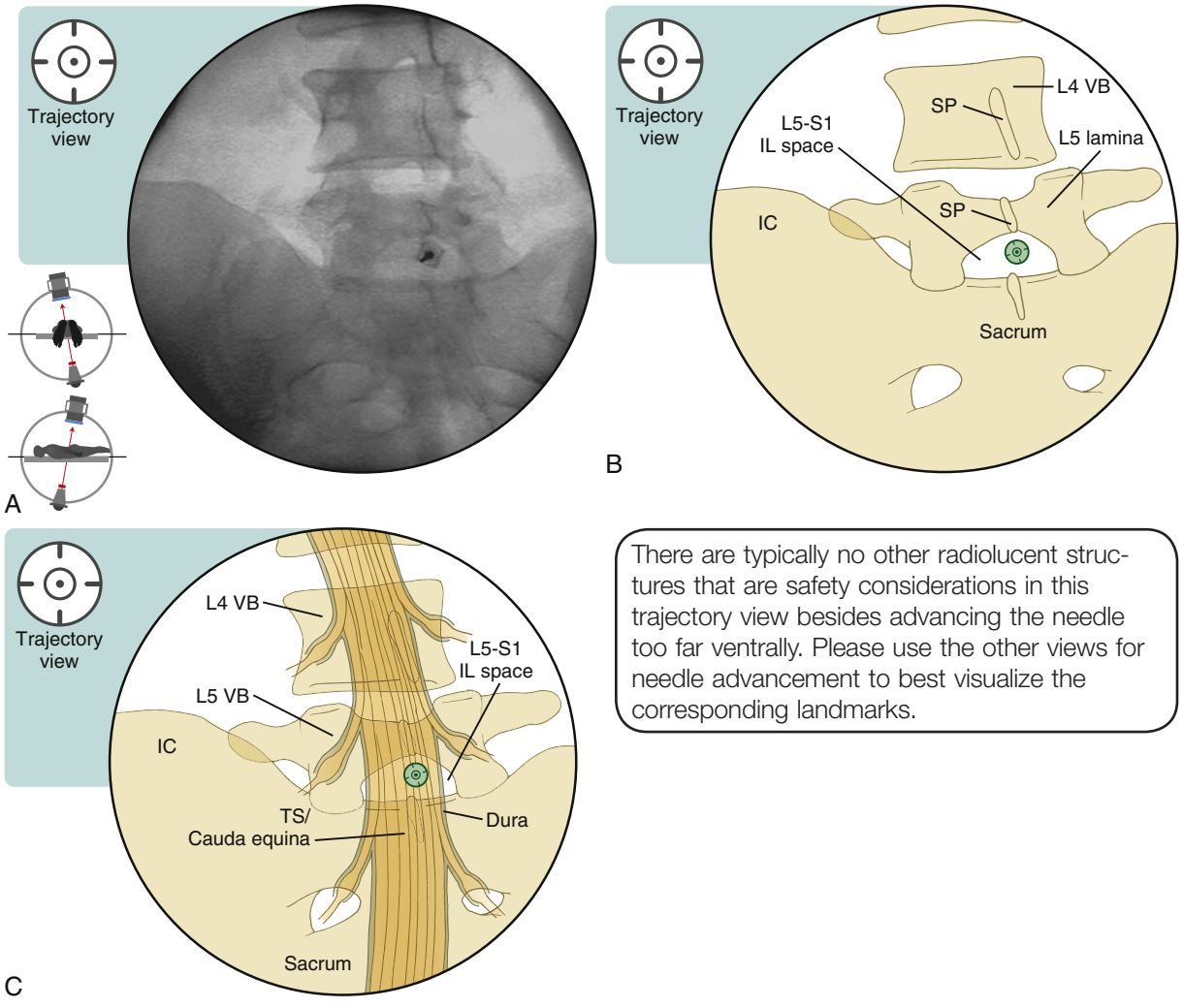

Fig. 12.1. A, Fluoroscopic image of a trajectory view with the needle in position at the L5-S1 interlaminar space, toward the left. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

Optimal Needle Positioning in the Anteroposterior View (Fig. 12.2)

After placing the needle in the trajectory view, oblique the C-arm back to a "true" anteroposterior view.

Notes on Anteroposterior View

- This view should be used to assess only mediolateral and superoinferior needle positions; it should not be used for any substantial ventral needle advancement.
- Ideally, place the needle tip on the more symptomatic side of the patient.

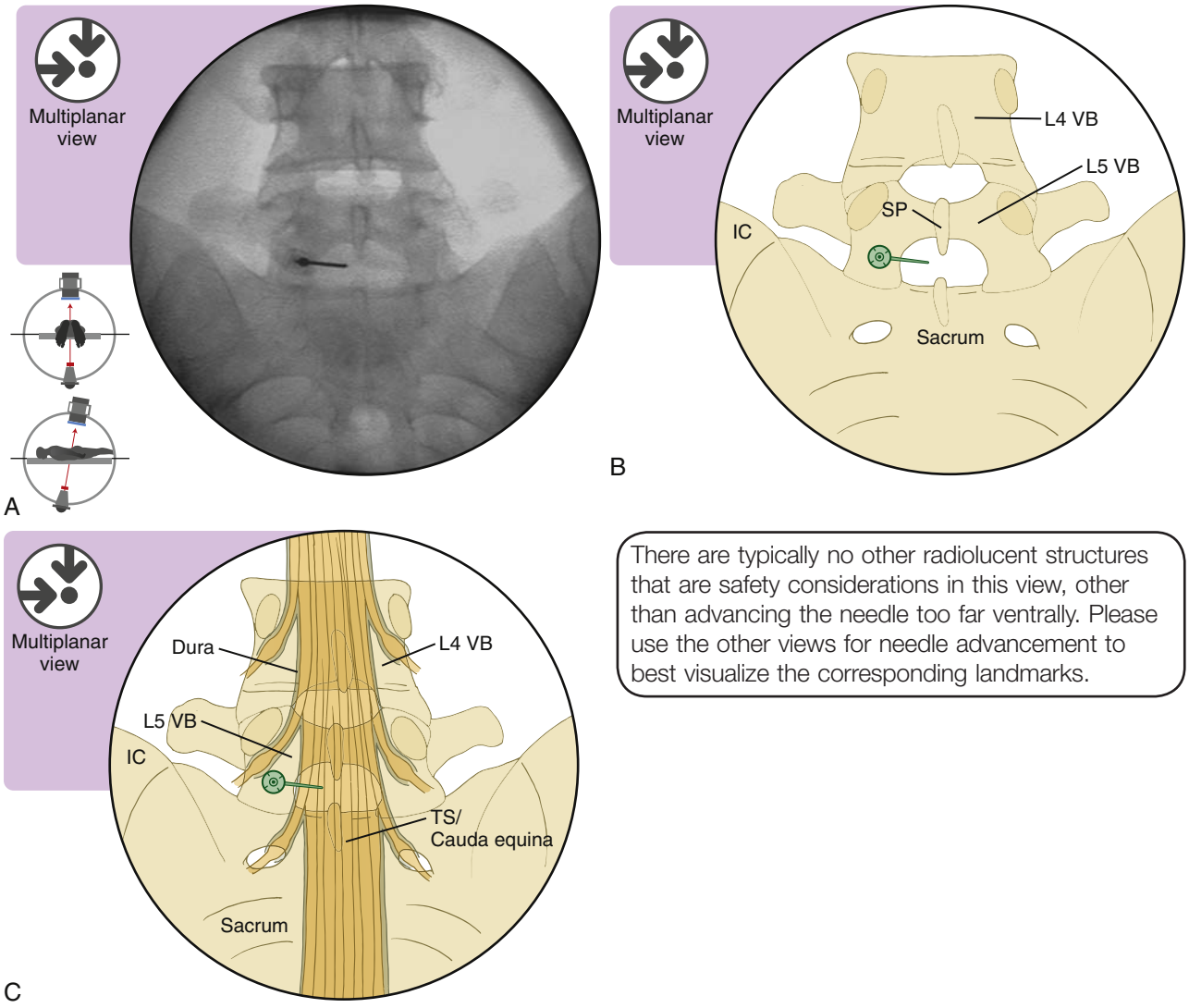

Fig. 12.2. A, Fluoroscopic anteroposterior view with ideal needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

OPTIMAL NEEDLE POSITION IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 12.3)

- When the needle is approaching the midline target as demonstrated by both the trajectory view and anteroposterior view, an oblique image contralateral to the needle tip is obtained.
- The C-arm should be oriented to obtain a CLO view (see Chapter 3). This is important for assessing the needle tip proximity to the VILL.

Notes on Optimal Needle Position

- Most needle advancement occurs in the CLO or lateral view as the dorsoventral depth is visualized.
- When the needle approaches the ventral aspect of the lamina (i.e., VILL), further advancement is performed with the use of the change-of-resistance technique.
- Periodically, during advancement, the physician may assess an anteroposterior view to ensure that the needle stays close to the midline (but remains on the most symptomatic side).
- After multiplanar imaging confirms epidural placement, further confirmation is done using the loss-of-resistance technique and live contrast injection.

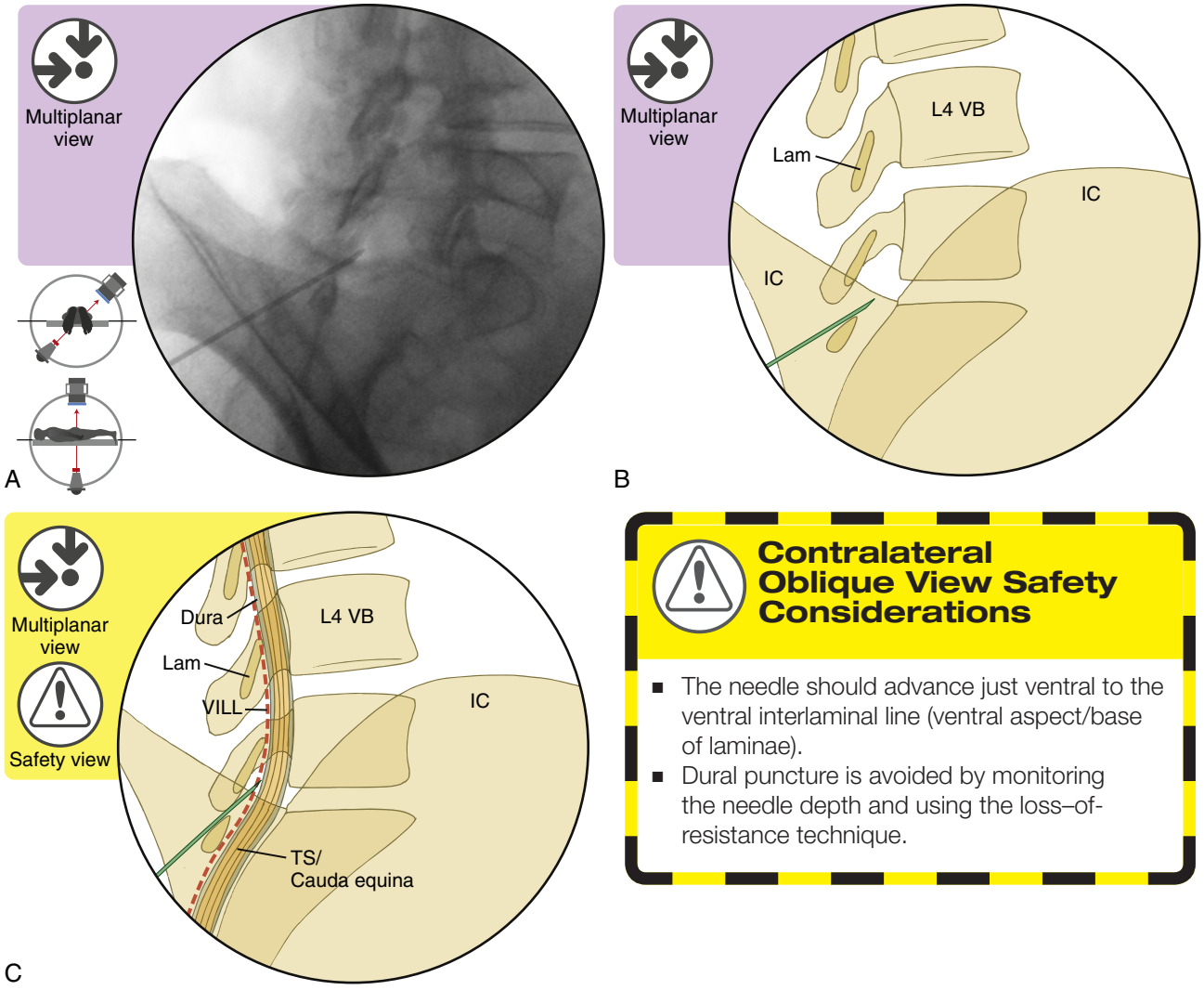

Fig. 12.3. A, Optional fluoroscopic contralateral oblique view with ideal needle position. **B,** Radiopaque structures, contralateral oblique view. **C,** Radiolucent structures, contralateral oblique view.

Optimal Needle Position in the Lateral View (Fig. 12.4)

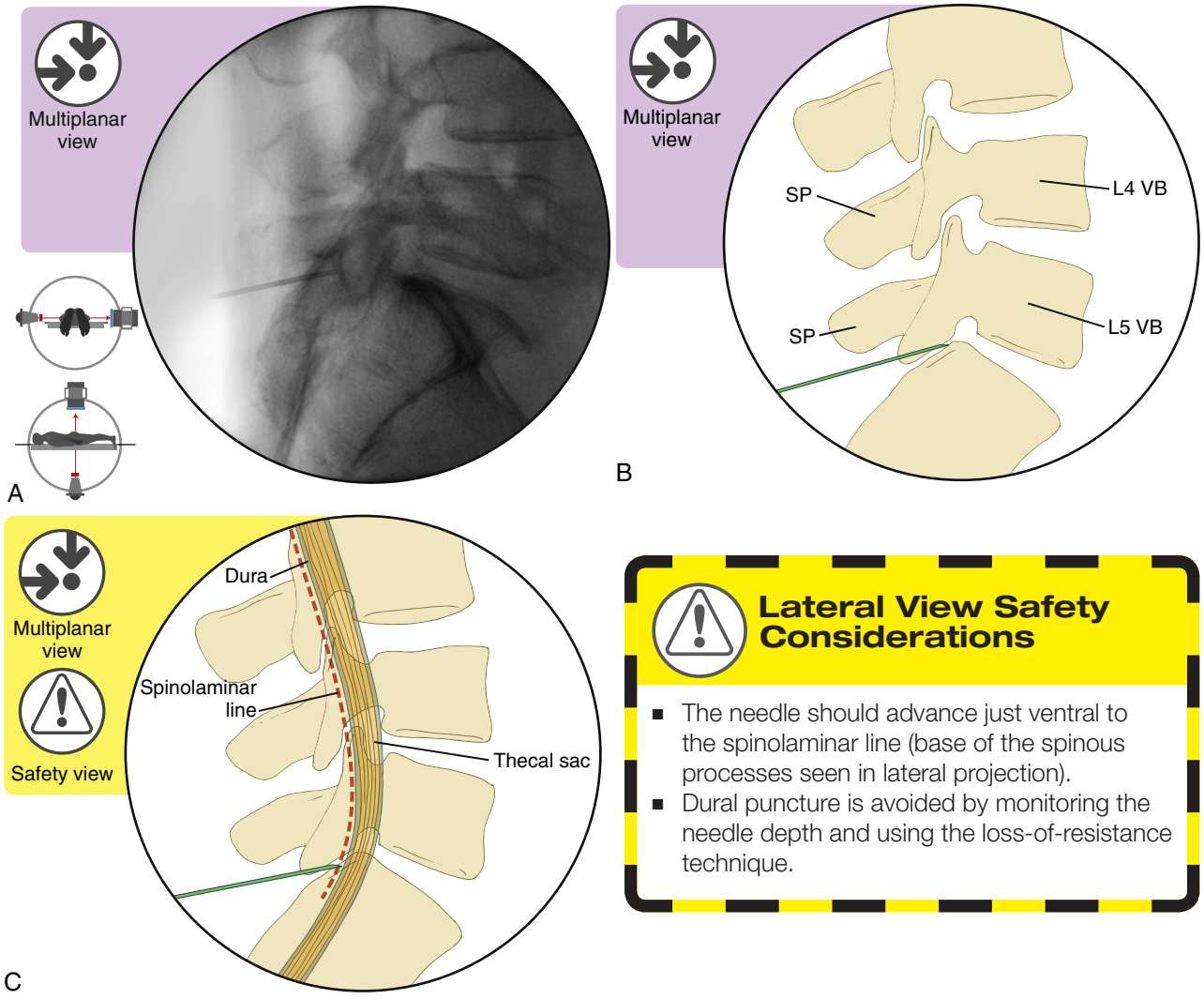

Fig. 12.4. A, Fluoroscopic lateral view with ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images (Figs. 12.5 to 12.6)

- After the loss of resistance is obtained and the location is confirmed using multiplanar imaging, live contrast flow is visualized.
- Contrast medium is typically deposited with a thick asymmetric pattern, and epidural fat bubbles are often visualized in the anteroposterior view and uniform flow ventral to the spinolaminar line is visualized on the lateral view and/or ventral to the VILL on the CLO view (see Table 12.1).
- See Chapter 3 for further description of the CLO view and CLO contrast flow patterns.

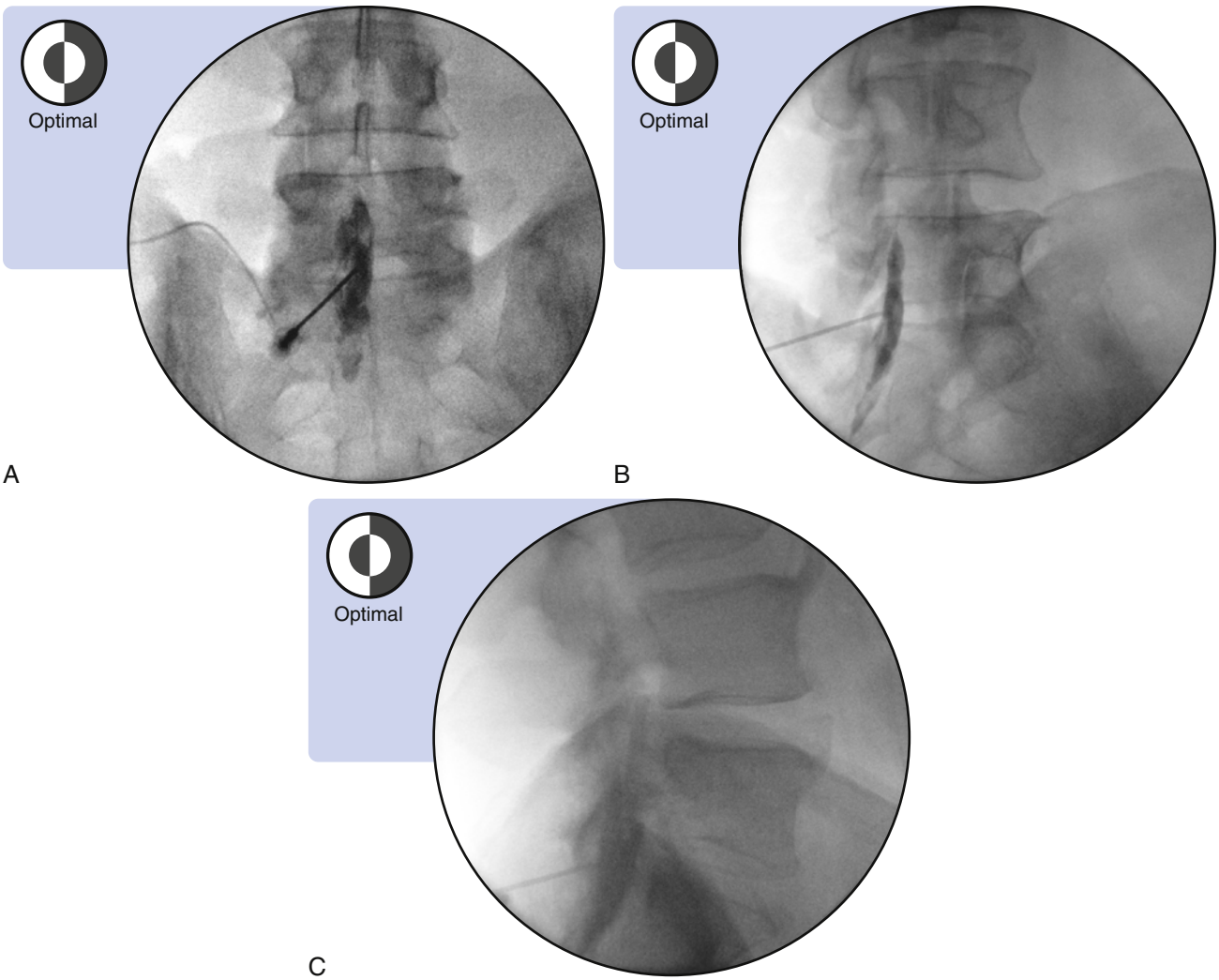

Fig. 12.5. A, Anteroposterior fluoroscopic image of a lumbar interlaminar epidural steroid injection with 0.5 cc of contrast medium. The contrast pattern is asymmetric. **B,** Contralateral oblique fluoroscopic image of a lumbar interlaminar epidural steroid injection with 0.5 cc of contrast medium. Optimal flow is seen as a thick pattern ventral to the ventral interlaminar line (VILL). **C,** Lateral fluoroscopic image of a lumbar interlaminar epidural steroid injection with 0.5 cc of contrast medium. Optimal flow is seen as a linear pattern ventral to the spinolaminar line (see Table 12.1, below).

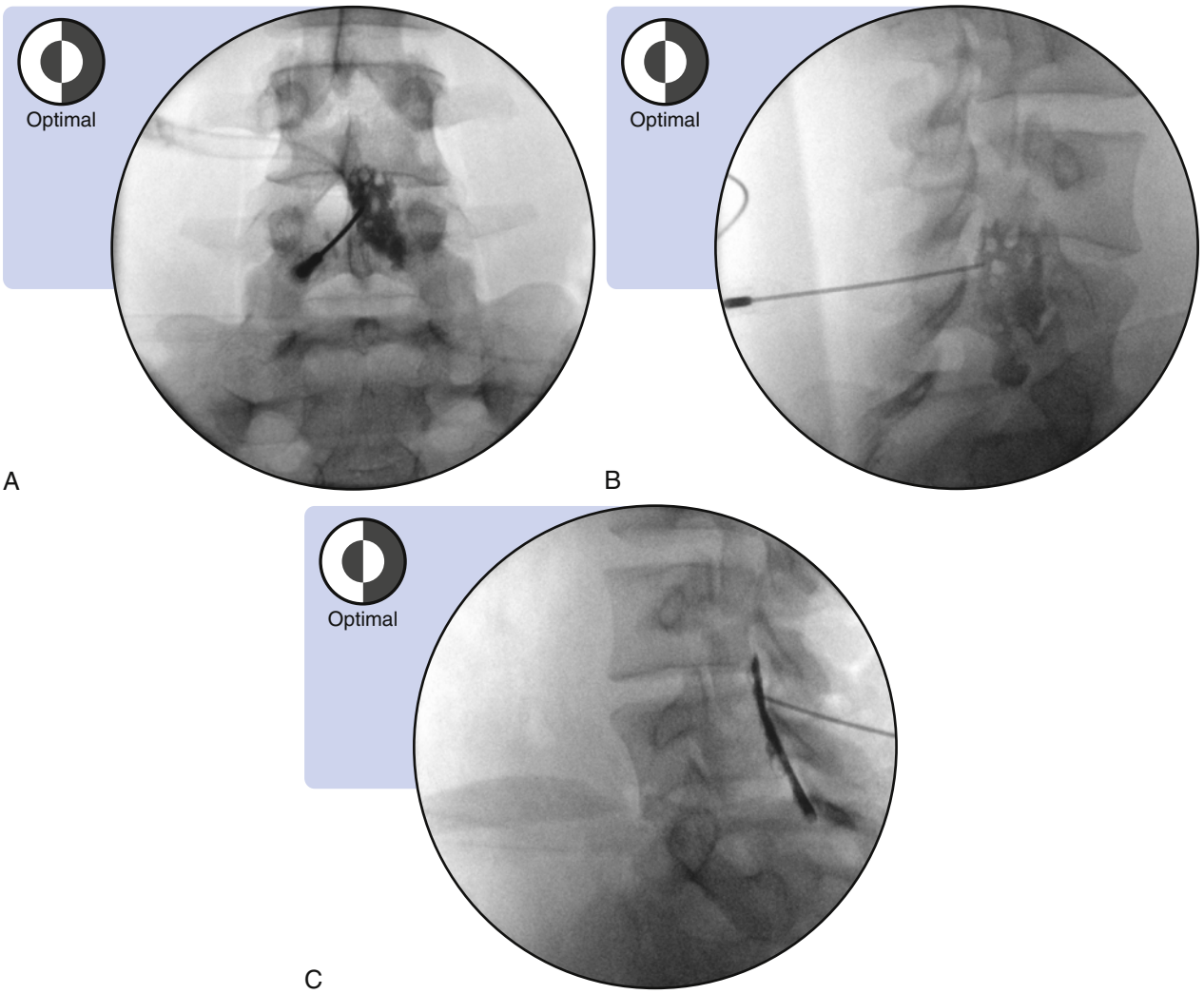

Fig. 12.6. These are "optimal" right-sided contrast patterns but would be considered "suboptimal" if the patient's symptoms and target are on the left. **A,** Anteroposterior (AP) view with right-sided contrast pattern demonstrates that the needle tip passed the midline with unilateral flow (contralateral to the patient's symptoms). **B,** Left L4-L5 interlaminar epidural steroid injection (ESI) with C-arm contralateral oblique to the right (ipsilateral to needle tip). Note that the dye pattern has a hazy dye pattern appearance on the contralateral oblique view in conjunction with the AP view, indicating that the needle tip has crossed the midline. **C,** Linear dye pattern in the same patient after the C-arm is oblique to the left (ipsilateral to needle entry but contralateral to the needle tip that has crossed midline). This confirms that the needle has passed the midline but is still present in the epidural space. If the patient's symptoms are left-sided, you need to consider readjusting the needle tip back to the intended left side. Please see Fig. 3.20 for drawings and discussion that will clarify these contralateral oblique dye patterns.

Table 12.1 Contrast Flow Pattern Characteristics Appreciated in Different Fluoroscopic Projections: "What to Expect When You Are Injecting".

	Example Figures	AP Characteristics	Oblique Characteristics	Lateral Characteristics	Potential Injection Outcome
Epidural (optimal)	11.4 to 11.6 14.10 (CT) 12.5 13A.4 to 13A.9 13B.4 to 13B.8 20.5 to 25.7 21.4 25.5 27.4 to 27.6	Vacuolization Asymmetric Contrast contacts medial pedicle (especially with TF-ESI)	Contrast contacts immediately ventral to the lamina along the VILL when the needle tip is contralateral	Uniform line ventral to the spinolaminar line ventral contrast uniformly contacts VB	Improvement
Subarachnoid (intrathecal)	12.7 14.4 to 14.8 14.9 (CT)	Hour-glass shape crosses midline Symmetric Contrast does NOT contact medial pedicle	Hazy dorsal fluid–fluid (CSF–contrast dye) level, with the distinct ventral dye layering dependently Contrast does NOT contact the VILL	Hazy dorsal fluid–fluid (CSF–contrast dye) level, with the distinct ventral dye layering dependently Contrast does NOT contact VB	Spinal headache Painful Injection Potential high sensory and/or motor block
Fascial/soft tissue	12.8	Localized	Localized contrast dorsal to VILL	Localized contrast dorsal to spinolaminar line	No improvement
Subdural (intradural)	12.9	Narrow pillar form Asymmetric or unilateral Contrast does NOT contact medial pedicle	Contrast does NOT contact the VILL	Extensive narrow, linear columns extending cephalad Contrast can spread dorsal or ventral but does NOT contact VB	Painful Injection High sensory and/or motor block
Subdural (intradural) dural boundary layer	14-10	Symmetric, bilateral Contrast approximates medial pedicle but does not exit foramina. "Tram Tracks"	Contrast approximates the VILL	Extensive narrow, linear columns extending cephalad Contrast dorsal and ventral but does consistently contact VB. "Tram Tracks"	High sensory and/or motor block

Suboptimal Images (Figs. 12.7 to 12.9)

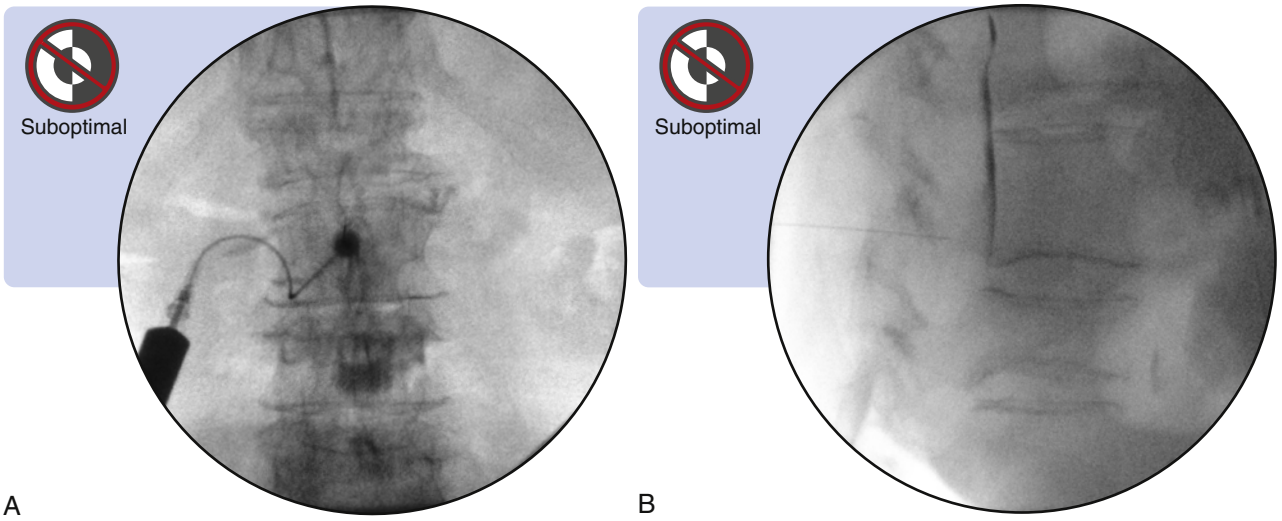

Fig. 12.7. A, Suboptimal lumbar interlaminar epidural steroid injection (ESI; intrathecal/subarachnoid pattern) in the anteroposterior view. This is actually an image taken from a myelogram with a small contrast volume. Note the near perfect symmetric flow, crossing the midline, outlining the thecal sac and exiting nerves with an "hour glass" shape. No epidural fat irregularities or vacuolization is visualized. There is a faint dye pattern. Live fluoroscopy would demonstrate the rapid dispersion of the contrast medium rostrally. Note that higher contrast volumes would demonstrate a thin epidural space between the lateral aspect of the outline of the thecal sac and the pedicle as shown in Chapter 14. **B,** Suboptimal lumbar interlaminar ESI in the lateral view. This is actually an image taken from a myelogram with a small contrast volume. The needle has advanced ventrally into the intrathecal (subarachnoid) space. Note the distinct ventral margin of the dye gravitationally pooling along the ventral thecal sac in this patient in the prone position and the hazy, more dorsal (CSF–contrast dye) fluid–fluid interface. Note that there is a thin epidural space between the thick dependent ventral aspect of the outline of the thecal sac and the vertebral bodies. See Chapter 14 for additional intrathecal/ subarachnoid flow patterns.

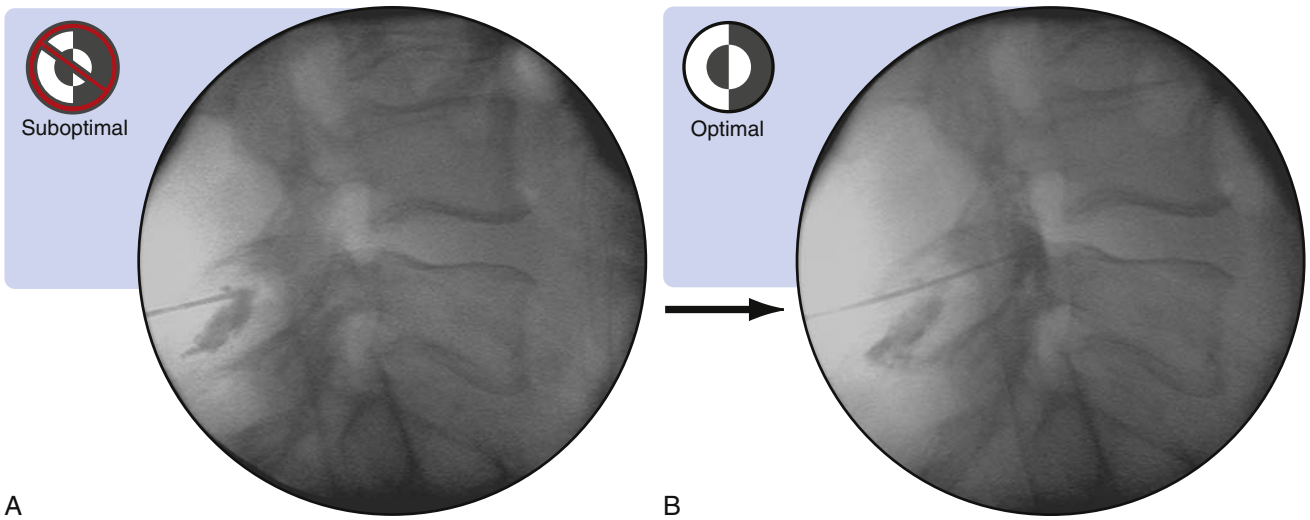

Fig. 12.8. A, Suboptimal lumbar interlaminar epidural steroid injection (ESI) in the lateral view with dorsal needle placement. The needle is located in the soft tissue/fascia dorsal to the spinolaminar line. Note the posterior "spilling" of contrast medium; this may occur when one encounters a false loss of resistance. **B,** Optimal lumbar interlaminar ESI in the lateral view. The needle has been advanced ventrally until a true loss of resistance occurred, after which an optimal image is visualized; this indicates correct placement in the epidural space.

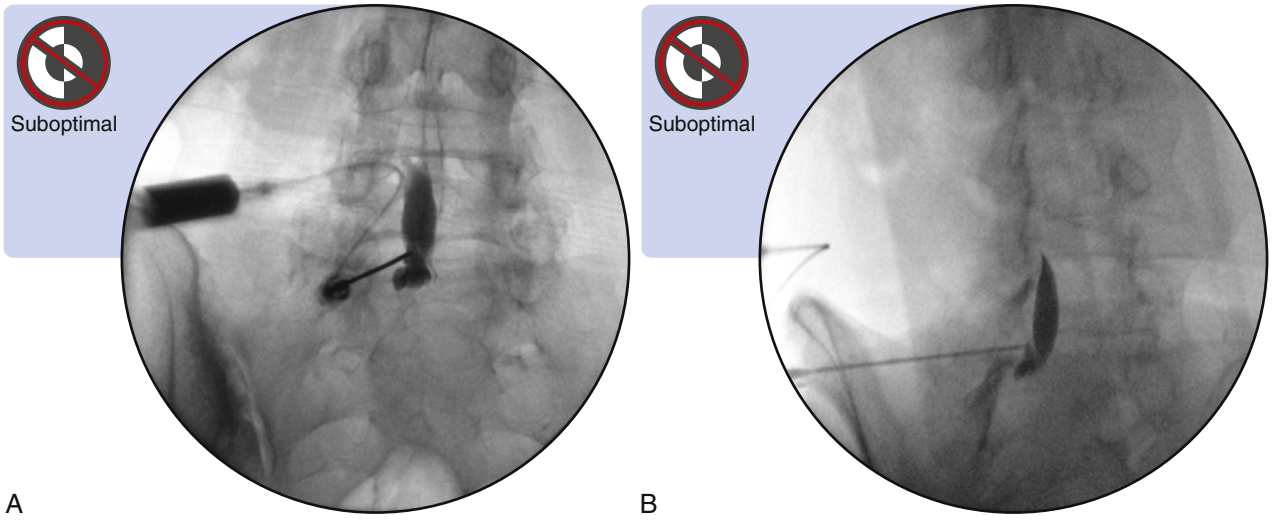

Fig. 12.9. Subdural pattern. **A,** Suboptimal lumbar interlaminar epidural steroid injection (ESI) in the anteroposterior view. Note the sharply delineated asymmetric, pillar form, subdural pattern without pertinent extension. No epidural fat irregularities are visualized. **B,** Suboptimal lumbar interlaminar ESI in the contralateral oblique view. The needle is located in the subdural (intradural) space. Note the sharply delineated subdural (intradural) pattern without pertinent extension of dye into the epidural space or without ventral and diffuse dye pattern consistent with an intrathecal injection. A contrast filling thin line is seen ventral to the VILL representing the epidural space.

Suggested Readings

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CHAPTER 13

Lumbar Transforaminal Epidural Steroid Injection

The transforaminal epidural steroid injection targets injectate delivery to the ventral epidural space.[1,2] Medication is placed at the suspected pathologic site that anatomically correlates with the patient's clinical and radiographic presentation. Because the injection is performed for therapeutic value, the medication should spread ventrally at the disc/thecal sac interface, medially around the pedicle and enter the epidural space with coverage of the exiting spinal nerve.

Other terminology used to describe this procedure (spinal nerve root block, selective nerve root block, and segmental nerve root block) implies diagnostic value of the procedure; however, literature has called this into question.[1,3-10]

Safety Considerations

Avoid the artery of Adamkiewicz (i.e., arteria radicularis magnus or ARM), which provides vascular supply to the spinal cord from T8 to the conus medullaris.

- The ARM most often enters the canal via neural foramen T12 through L3, but the ARM or a radiculomedullary feeder artery may be present at any level.
  - Avoid advancing the needle to the ventral floor of the neural foramen to minimize the risk of cannulating the artery of Adamkiewicz for levels at or superior to L3.[13,26-29]
  - Anatomic studies demonstrate ARM entry on the left side with 78% to 82% incidence.
  - There is a high degree of anatomic variation in the level and side of ARM entry.[13,26-29]

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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CHAPTER 13A

Lumbar Transforaminal Epidural Steroid Injection—Supraneural (Traditional) Approach: Fluoroscopic Guidance

Leland Berkwits, Simon J. Shapiro, Scott J. Davidoff, Charles J. Buttaci, and Michael B. Furman

Traditionally, the transforaminal approach to epidural steroid injection is accomplished with a supraneural (subpedicular or retroneural) needle position. The target resides within the "safe triangle" location which is where a lumbar transforaminal injection can be accomplished with minimal risk of intrathecal or neural injury.[11,12] The technique described in this chapter differs from the subpedicular approach described elsewhere,[15] since the needle is not advanced completely to the ventral aspect of the vertebral body. Avoiding the vertebral body theoretically reduces the likelihood of vascular injection, but vascular compromise may still occur. Although complications are rare, conus infarct has been reported with this approach.[13,14] Catastrophic events are thought to be from embolization caused by particulate corticosteroids entering the spinal cord and/or brain arterial supply.[13,14] For this reason, we advocate strong consideration for using non-particulate steroids since their "noninferiority" has been demonstrated.[15,16]

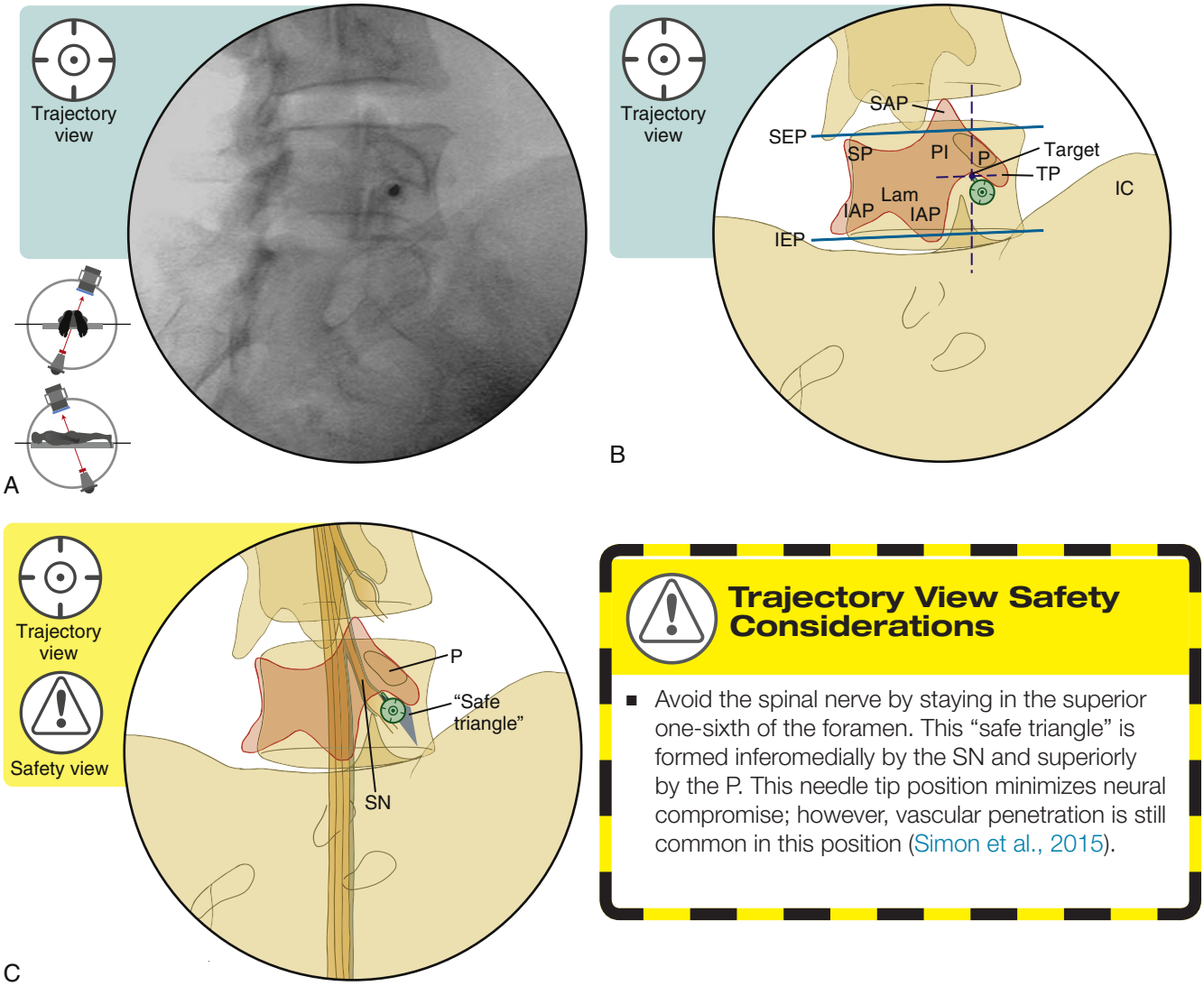
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

- **Confirm the level** (see Chapter 1).
- **Tilt the fluoroscope cephalad or caudad to line up the superior end plate (SEP) corresponding to the vertebra at which the injection is being performed.** SEP should appear as a straight line (Fig. 13A.1), rather than an elliptical structure, indicating that the fluoroscope beam is aligned with the superior end plate (SEP).
- Preferentially lining up the SEP rather than the inferior end plate (IEP) will favor an inferior-to-superior needle trajectory (with the final needle tip position more likely to target the supraneural location).
- **Oblique the fluoroscope** ipsilateral to allow for proper visualization of the target point and, therefore, optimal trajectory for supraneural needle placement avoiding encountering the spinal nerve (SN) (see Fig. 13A.1).
- Note the following anatomic landmarks that create the "Scotty dog": Pedicle (P) = eye, transverse process (TP) = nose, pars interarticularis (PI) = neck, inferior articular process (IAP) = front and rear legs, superior articular process (SAP) = ear, spinous process (SP) = tail, and lamina (Lam) = body.
- The target needle destination is just below the "chin" of the "Scotty dog" (i.e., adjacent to the pars interarticularis and inferior to the pedicle) where there is no periosteum (SAP, TP, Lam, PI) obstructing the target point.
- Avoid advancing the needle too far medially to prevent penetration of the dural sheath.
- A **more medial** final needle tip placement requires a **more oblique** approach.
- **Identify a direct path** to reach the target needle position.
- **Place the needle parallel to the fluoroscopic beam.**

Notes on Trajectory View Setup (See Chapter 13D for additional diagrams)

- Oblique ipsilaterally until there is no periosteum (SAP, TP, lamina, and PI) obstructing the target point beneath the "chin" of the "Scotty Dog."
- **A more oblique trajectory** results in a **more medial** final needle tip position (on the anteroposterior [AP] view) and a **less ventral** final needle tip position (on the lateral view). This approach may facilitate access to the neural foramen in individuals with foraminal stenosis.
- **A less oblique trajectory** results in a **less medial** final needle tip position (on the AP view) and a **more ventral** final needle tip position (on the lateral view).
- In a scoliotic spine, lining up the SEP may not result in an optimal needle trajectory. The needle trajectory may need to be further "tuned" by adjusting the fluoroscope tilt cephalad or caudad to optimize SEP visualization (see Chapter 3, "Tuning" an Oblique View for Optimal Needle Trajectory, Figs. 3.27A to 3.27C.)
- For L5, the iliac crest may obstruct a clear trajectory. Adjust the C-arm to a more cephalad tilt and/or reduce the oblique angle until an unobstructed trajectory is achieved.



Trajectory View Safety Considerations

- Avoid the spinal nerve by staying in the superior one-sixth of the foramen. This "safe triangle" is formed inferomedially by the SN and superiorly by the P. This needle tip position minimizes neural compromise; however, vascular penetration is still common in this position (Simon et al., 2015).

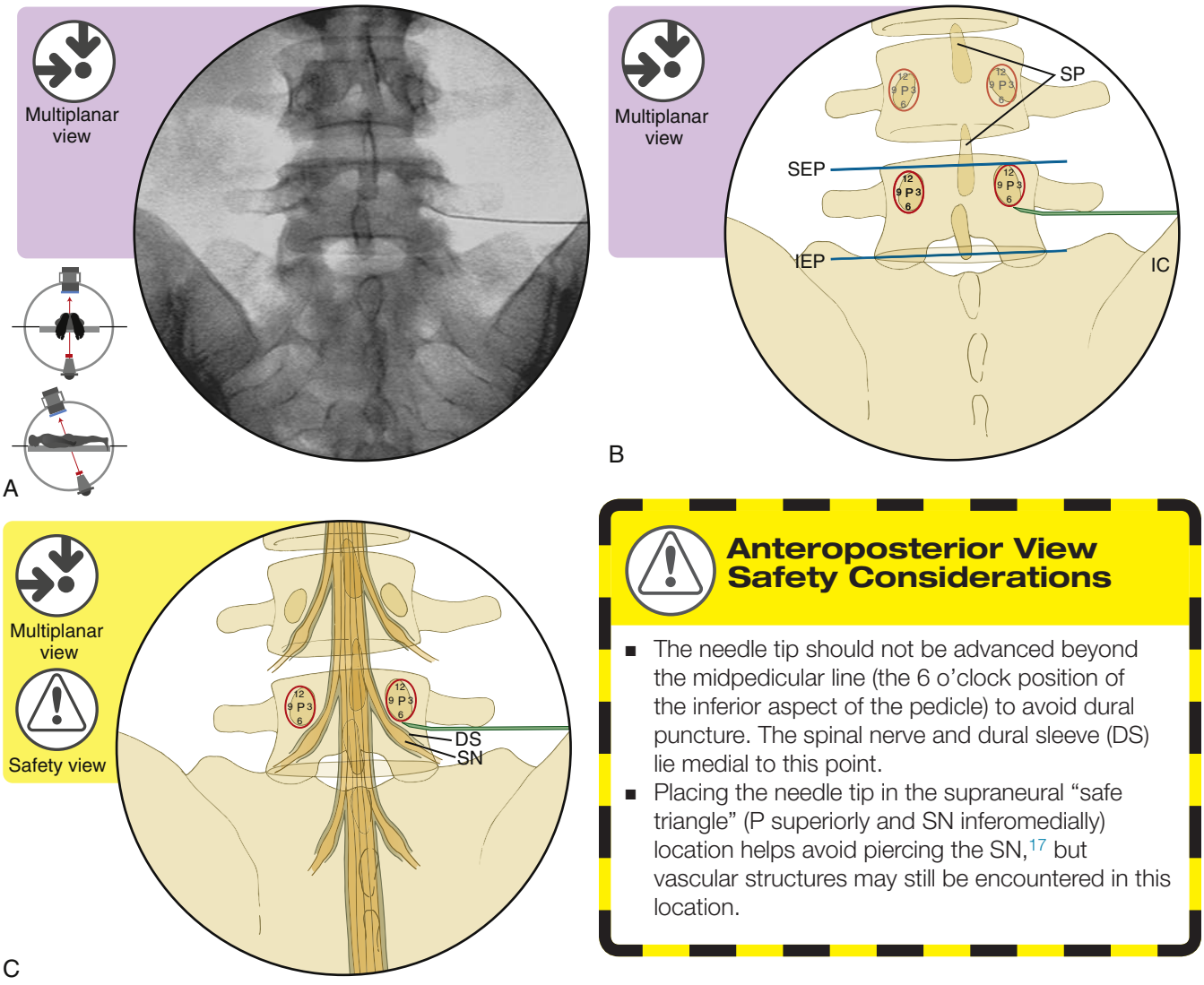
Fig. 13A.1. A, Fluoroscopic image of the trajectory view with needle in position. **B,** Radiopaque structures, trajectory view. Note the "Scotty Dog": P = eye, TP = nose, PI = neck, IAP = front and rear legs, SAP = ear, SP = tail, and Lam = body. **C,** Radolucent structures. Note the "safe triangle" formed inferomedially by the SN and superiorly by the P.

Optimal Needle Position in Multiplanar Imaging

See Chapter 13D: Lumbar Transforaminal Epidural Steroid Injection: Needle Localization Diagram.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW

- SEP and IEP are optimized by adjusting the cephalad or caudad tilt of the fluoroscopic beam.
- The SP is midline, and the Ps are equidistant from the midline (Fig. 13A.2).



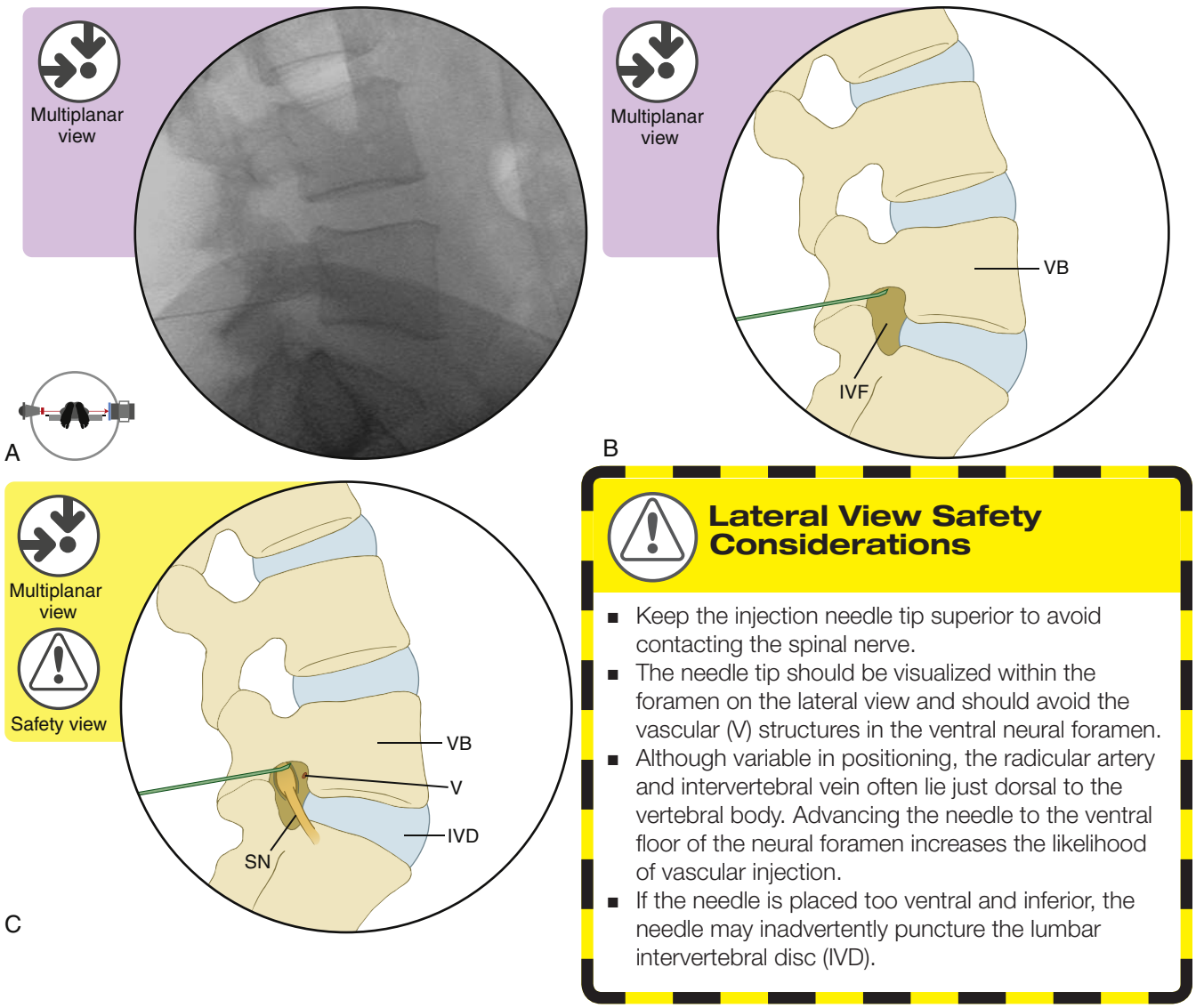
Anteroposterior View Safety Considerations

- The needle tip should not be advanced beyond the midpedicular line (the 6 o'clock position of the inferior aspect of the pedicle) to avoid dural puncture. The spinal nerve and dural sleeve (DS) lie medial to this point.
- Placing the needle tip in the supraneural "safe triangle" (P superiorly and SN inferomedially) location helps avoid piercing the SN,[17] but vascular structures may still be encountered in this location.

Fig. 13A.2. A, Fluoroscopic anteroposterior view with ideal needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view. Note the supraneural "safe triangle" created by the pedicle *(P)* superiorly and spinal nerve *(SN)* inferomedially.

Optimal Needle Positioning in the Lateral View

- Confirm a true lateral by optimizing the view of SEP and IEP. Adjust the patient or wig-wag the fluoroscope (Fig. 13A.3).
- If the needle is advanced or withdrawn in the lateral view, another AP view should be obtained to confirm that the needle has not advanced medial to the 6 o'clock position under the pedicle.



Lateral View Safety Considerations

- Keep the injection needle tip superior to avoid contacting the spinal nerve.
- The needle tip should be visualized within the foramen on the lateral view and should avoid the vascular (V) structures in the ventral neural foramen.
- Although variable in positioning, the radicular artery and intervertebral vein often lie just dorsal to the vertebral body. Advancing the needle to the ventral floor of the neural foramen increases the likelihood of vascular injection.
- If the needle is placed too ventral and inferior, the needle may inadvertently puncture the lumbar intervertebral disc (IVD).

Fig. 13A.3. A, Fluoroscopic lateral view with ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images

Ideal flow should outline the spinal nerve and nerve root sheath, and then flow into the epidural space medial to the pedicle at the suspected site of pathology (Figs. 13A.4 to 13A.9):

- For a centrally herniated intervertebral disc, the flow should reach the suspected disc level.
- For a foraminal herniated intervertebral disc or foraminal stenosis, the flow should ideally cover this foraminal pathology.

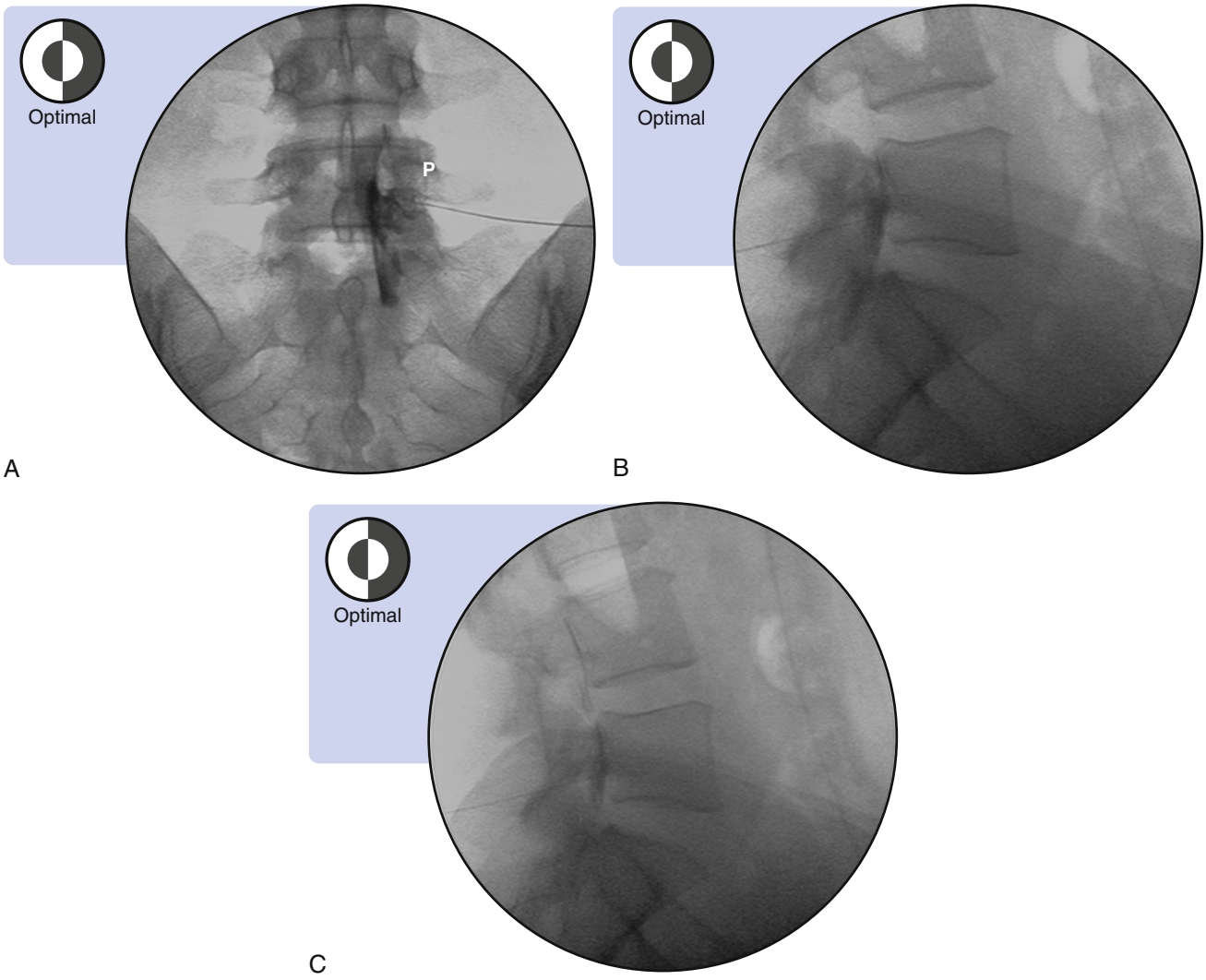


Fig. 13A.4. A, Anteroposterior fluoroscopic image of a right L5 transforaminal epidural steroid injection with 1 cc of contrast medium. **B,** Lateral fluoroscopic image of right L5 transforaminal epidural steroid injection with 1 cc of contrast medium. **C,** Lateral fluoroscopic image of the same right L5 transforaminal epidural steroid injection taken several minutes after the original contrast injection. Note how the contrast has spread cephalad within the epidural space.

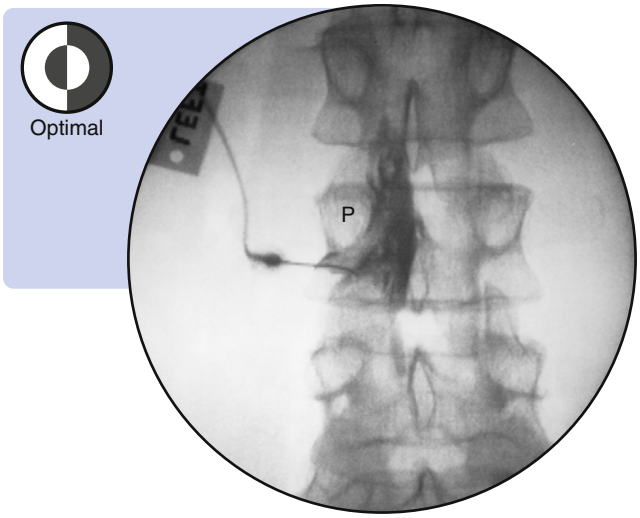


Fig. 13A.5. Note the more superior than inferior flow of contrast within the epidural space in this patient.

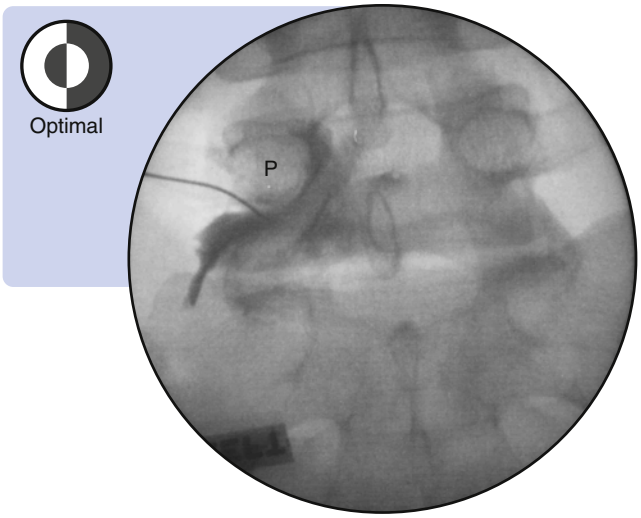


Fig. 13A.6. The contrast is outlining the exiting L5 spinal nerve. It flows medially around the pedicle and then spreads superiorly within the epidural space.

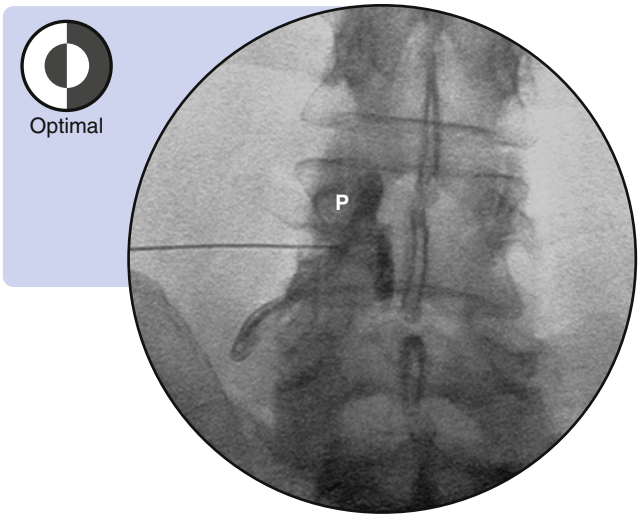


Fig. 13A.7. Note both the superior and inferior spread of contrast within the epidural space.

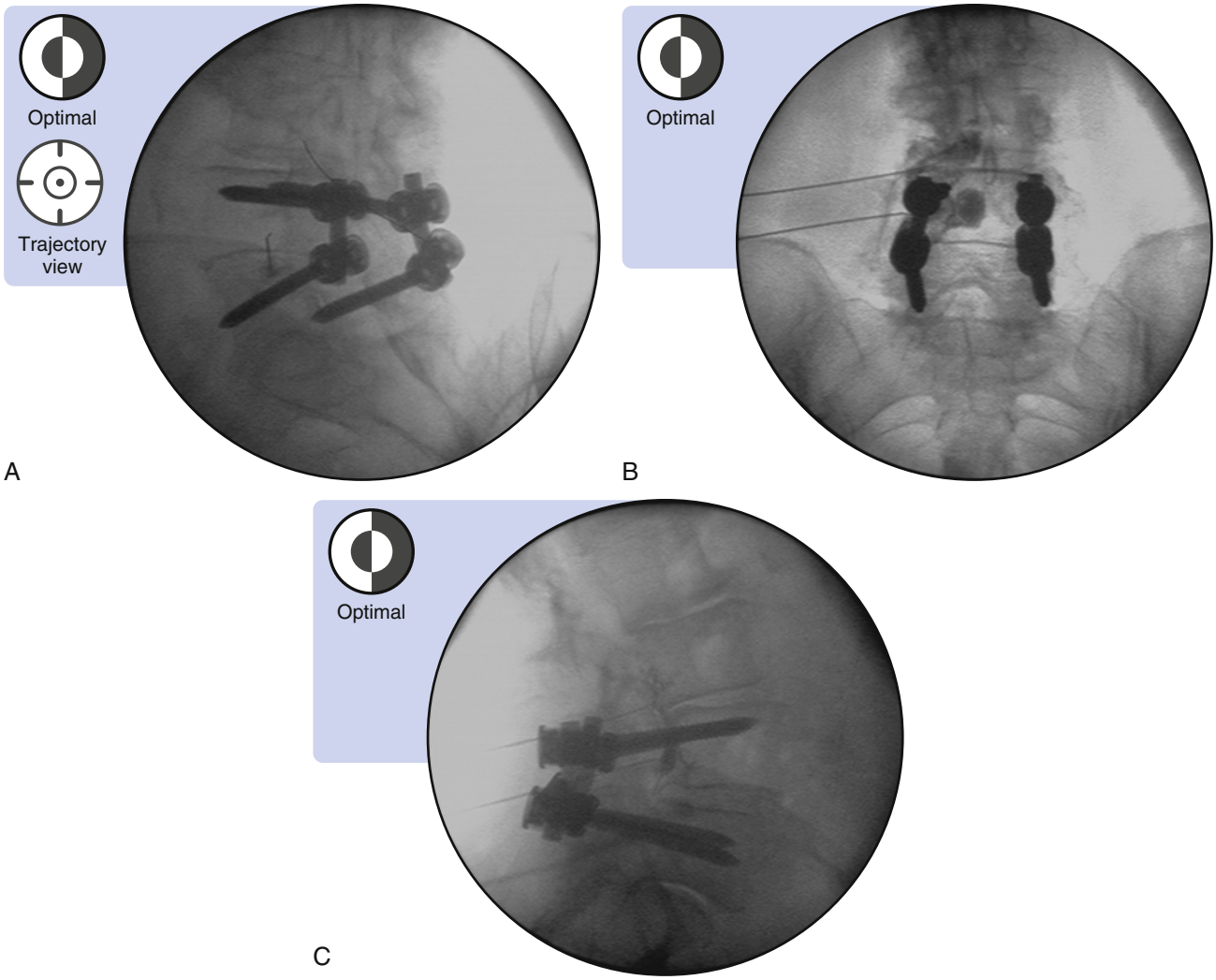


Fig. 13A.8. A, For a patient with a hardware or fusion mass (L4-L5 fusion, in this case), use a more oblique trajectory as seen at the left L4 level, for a more lateral-to-medial trajectory. The target remains under the pedicle. This angle allows the needle to ventrally bypass the obstructing fusion mass on its way into the foramen. Note how the trajectory for L4 (lower) is much more oblique than that for the L3 level. **B,** Anteroposterior view with contrast demonstrates flow medial to the pedicle at L4 and into the epidural space. **C,** Lateral view demonstrates needle placement ventral to the fusion, with contrast flow in the epidural space.

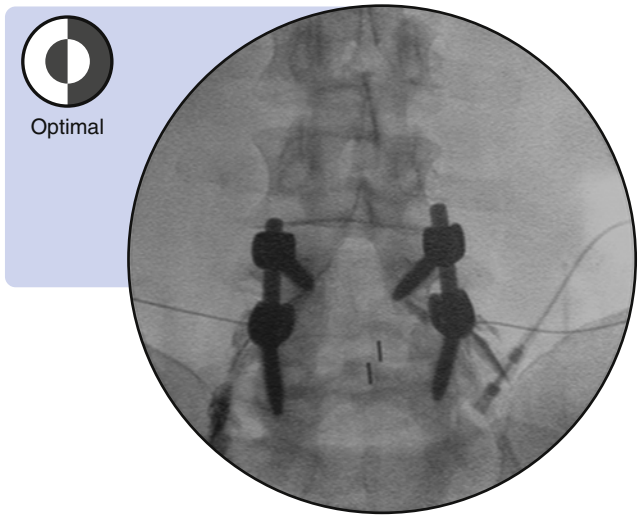


Fig. 13A.9. Anteroposterior view with contrast demonstrates flow medial to the pedicle bilaterally at L4 and in the epidural space.

Suboptimal Images

- Avoid any contrast flow pattern that does not ideally outline the targeted structures.
- If vascular flow cannot be avoided, the procedure should be terminated without steroid injection.
- Avoid a dural puncture and intrathecal or subdural flow (Figs. 13A.10 to 13A.16). See Table 12.1: Contrast Flow Pattern Characteristics Appreciated in Different Fluoroscopic Projections—"What to expect when you are injecting."

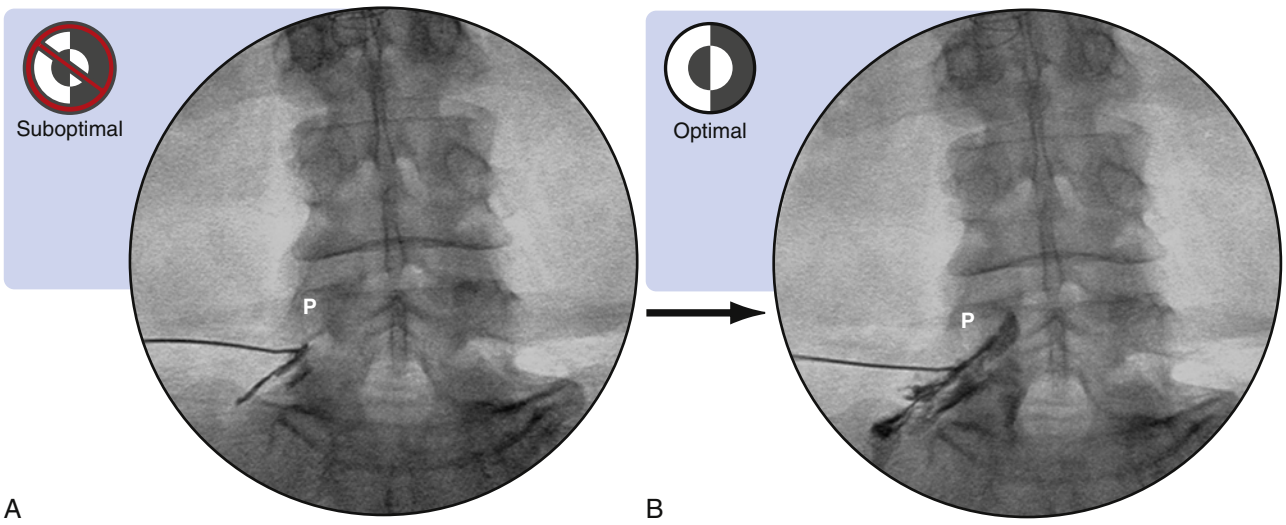


Fig. 13A.10. A, Anteroposterior view demonstrating that flow is limited to the exiting spinal nerve. The needle should be repositioned so that the contrast flow is medial to the pedicle *(P)* and into the epidural space. If left as seen in Fig. 10.10A, this contrast flow pattern resembles a "selective" spinal nerve block or a ventral ramus block because it does not flow into the epidural space. **B,** After repositioning the needle medially, this anteroposterior fluoroscopic image now demonstrates optimal flow for a therapeutic procedure.

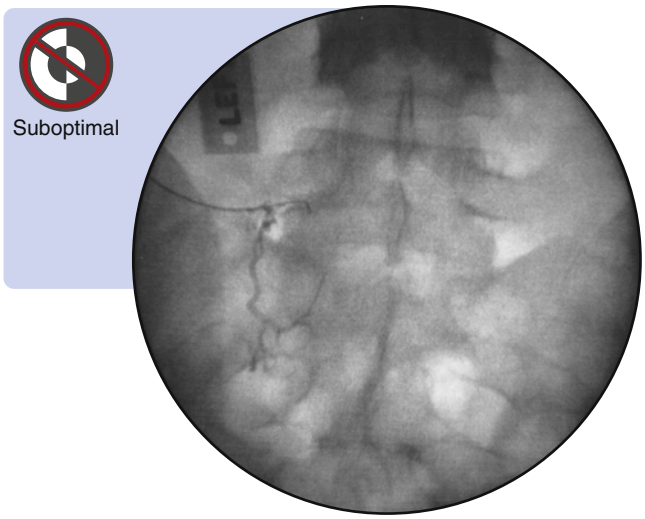


Fig. 13A.11. This fluoroscopic image demonstrates vascular flow. Although the image above is static, when it is observed under live fluoroscopy, the contrast rapidly dissipates. If vascular flow persists, the procedure should be terminated without steroid injection at that level.

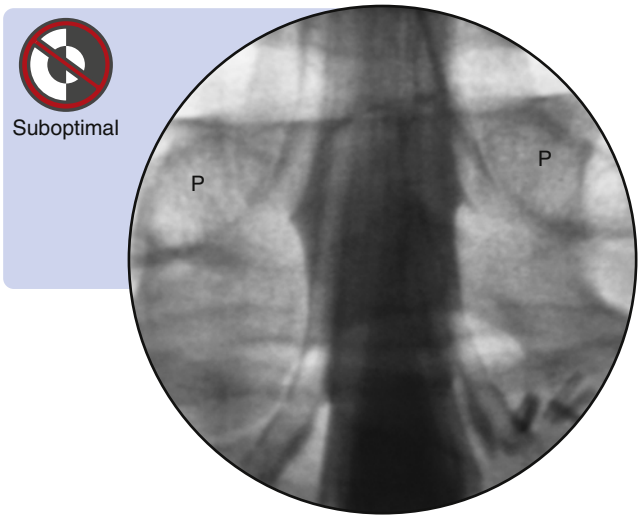


Fig. 13A.12. Myelogram. This picture from a myelogram demonstrates intrathecal flow. Note how the contrast fills up the dura medial to the 6 o'clock position of the pedicle *(P)*. For further discussion and flow comparisons see Table 12.1. Contrast Flow Pattern Characteristics Appreciated in Different Fluoroscopic Projections.

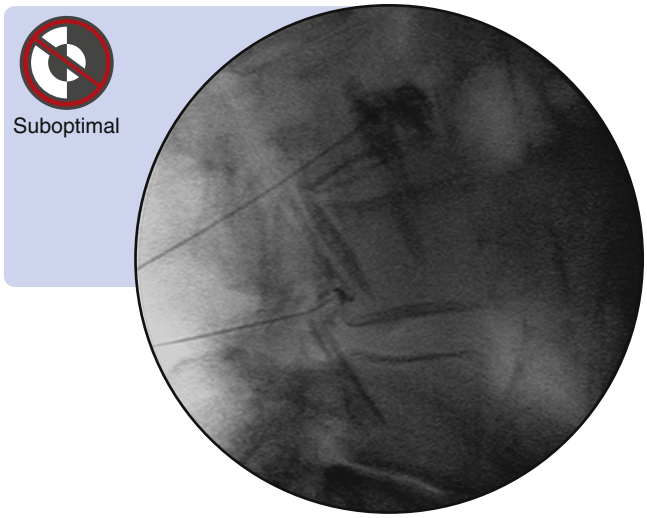


Fig. 13A.13. The lateral view of a two-level (L3 and L4) transforaminal epidural steroid injection demonstrates needle placement ventral to the foramen at the superior (L3) level with associated suboptimal, nonepidural flow.

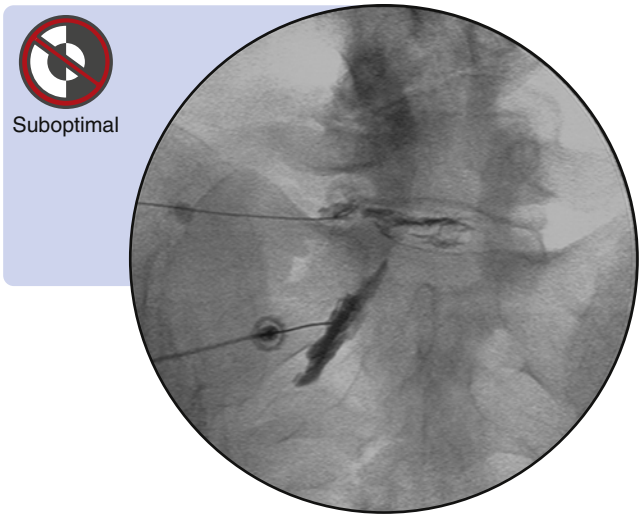
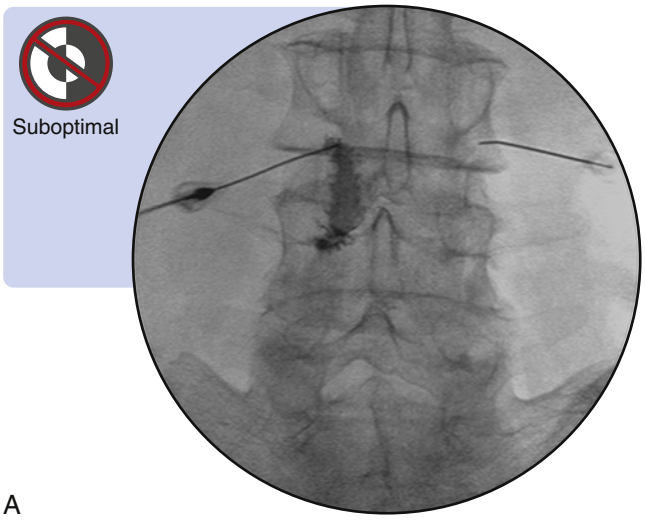
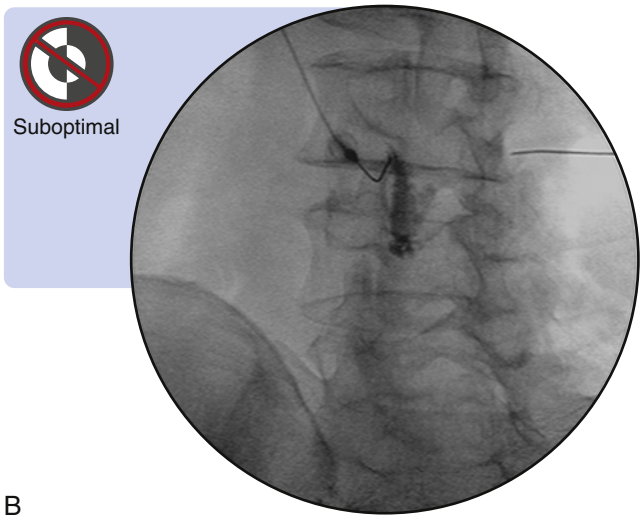


Fig. 13A.14. The needle for the intended L5 transforaminal injection was placed too inferior (i.e., "low in the hole") and subsequently advanced too ventral. The contrast is visualized within the disc.



A



B

Fig. 13A.15. A, For patients with hypertrophied zygapophysial joints (Z-joints), a medial needle placement may result in an inadvertent Z-joint injection, as seen on this anteroposterior view of an attempted left L3 transforaminal contrast injection. Be suspicious of a Z-joint injection whenever contrast flows inferiorly similar to the pattern shown here. **B,** When Z-joint placement is suspected, confirmation is obtained with an ipsilateral oblique view to better visualize Z-joint filling. The needle must be withdrawn and redirected more superiorly (and sometimes laterally) under the pedicle and ventral (deeper) to bypass the Z-joint and enter the foramen.

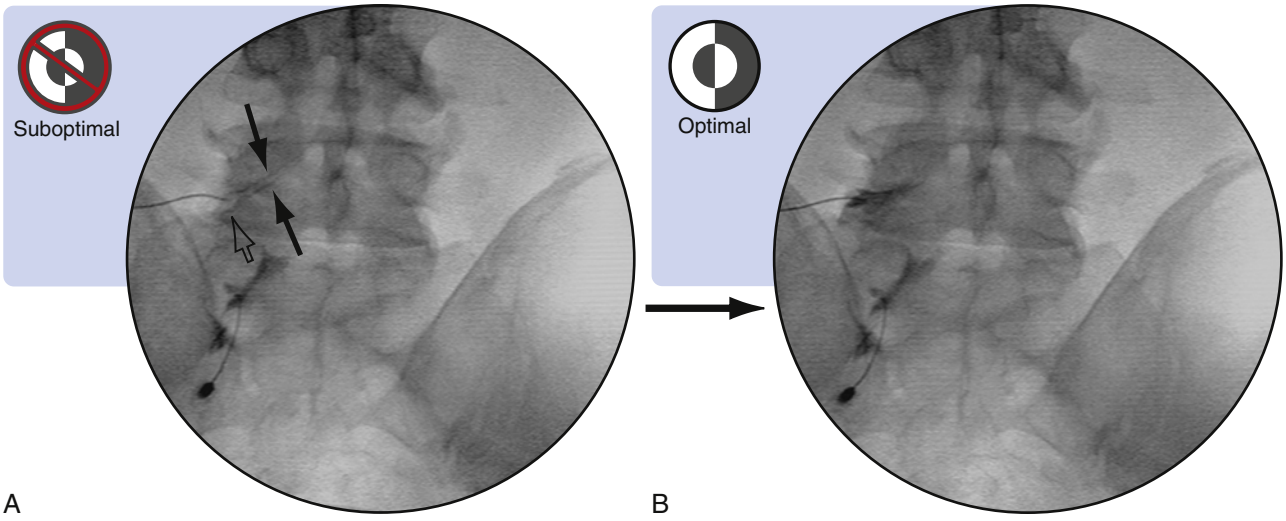


Fig. 13A.16. A, Anteroposterior view of the left L5 and S1 transforaminal epidural steroid injections. Note that the L5 contrast flow pattern demonstrates "train tracks" *(black arrows)* after a painful intraneural injection. The contrast outlines the dorsal root ganglion *(open arrow)* as well. Further injection before the needle is repositioned is not recommended. **B,** After pulling back slightly on the L5 needle and confirming a perineural injection, injectate can be placed much more comfortably.

Video 13A.1. A, Fluoroscopic live video of an optimal L3 transforaminal epidural steroid injection (ESI). **B,** Live digital subtraction video of the same L3 transforaminal ESI.

Video 13A.2. Suboptimal filling of a left L4 transforaminal epidural steroid injection (ESI) observed with digital subtraction fluoroscopy. Note the pulsatile pattern superiorly and subtle vascular pattern inferiorly.

Video 13A.3. Suboptimal filling of a left L5 transforaminal epidural steroid injection (ESI) observed with fluoroscopy.

Reference

1. Simon JI, McAuliffe M, Parekh NN, Petrolla J, Furman MB. Intravascular penetration following lumbar transforaminal epidural injections using the infraneural technique. *Pain Med*. 2015 Aug;16(8):1647–1649.

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CHAPTER 13B

Lumbar Transforaminal Epidural Steroid Injection—Supraneural, Two-Needle Technique: Fluoroscopic Guidance

Dallas Kingsbury, Gregory Lutz, Jonathan S. Kirschner, and Michael B. Furman

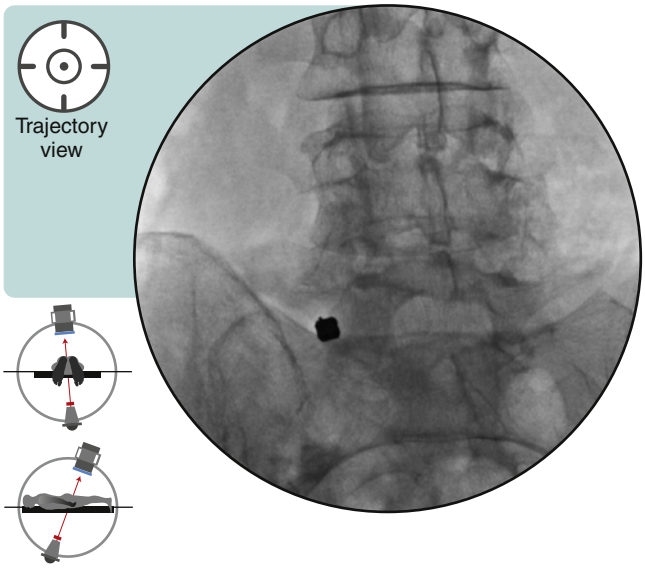
The two-needle (aka double needle) technique is a common method used to access the intradiscal space but may also be utilized to perform supraneural and infraneural transforaminal epidural injections. One advantage of this technique is increased maneuverability to bypass barriers (hardware, osteophytes, fusion masses, etc.) to the target zone, since an appropriately bent injection needle through an introducer tip can be driven medially with little ventral movement. The introducer tip creates a new point of trajectory from which more extreme directions can be achieved at target depth. We will describe trajectory and multiplanar views for introducer needle placement and multiplanar views for a supraneural injection needle placement. Although not demonstrated in this atlas, the two-needle technique can also be used for infraneural injection needle tip placement.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

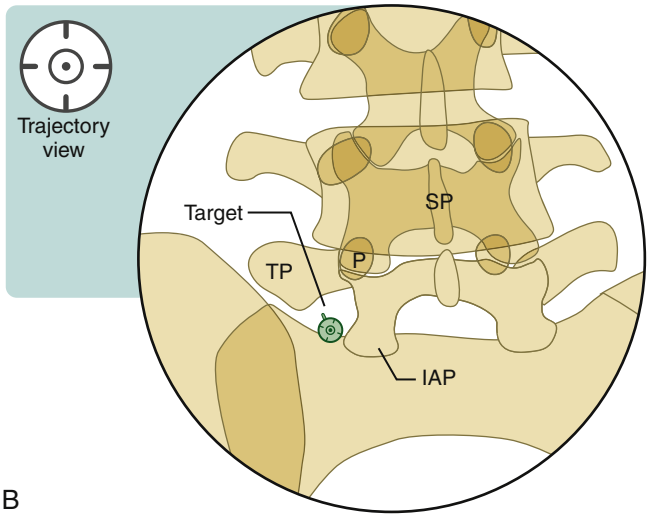
Phase 1: Introducer Needle Placement

Trajectory View

- **Confirm the level** (see Chapter 1).
- **Tilt the fluoroscope** cephalad or caudad to line up the corresponding superior end plate (SEP) as in Chapter 13A (supraneural approach).
  - Oblique the fluoroscope ipsilaterally.
  - **The target introducer needle starting point is** lateral to the pedicles and between the transverse processes (if performing an L1-L4 transforaminal epidural steroid injection [TF-ESI]) or between the L5 transverse process and the sacral ala (if performing an L5 TF-ESI) The target should have a clear, unobstructed path that does not overlie the periosteum (see Fig. 13B-01A and 01B).
  - **Place the introducer needle parallel to the fluoroscopic beam**, gain purchase in paraspinal musculature, and then move on to the AP view.



A



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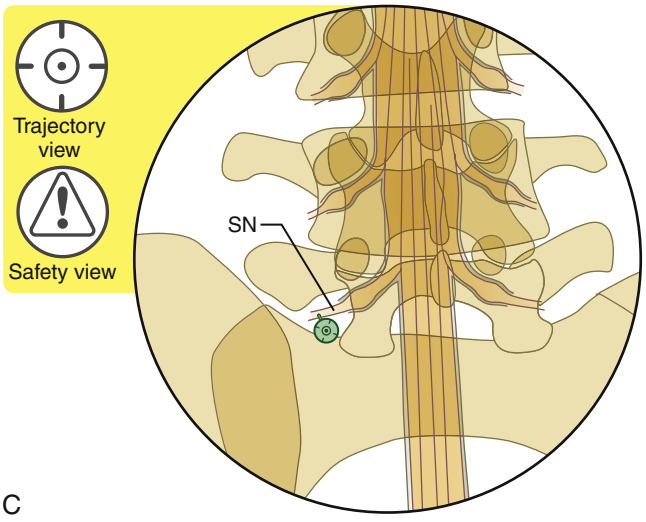


C

Trajectory View Safety Consideration

- Avoid contacting the spinal nerve (SN) with the introducer needle by staying superior to it.
- Use AP and lateral views for further safety considerations.

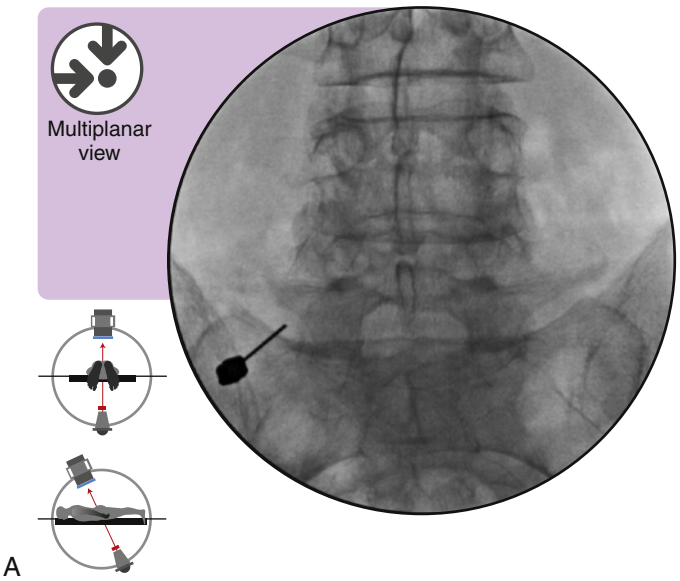
Fig. 13B.1. A, Fluoroscopic image of trajectory view with introducer needle in position. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging (Introducer Needle Placement)

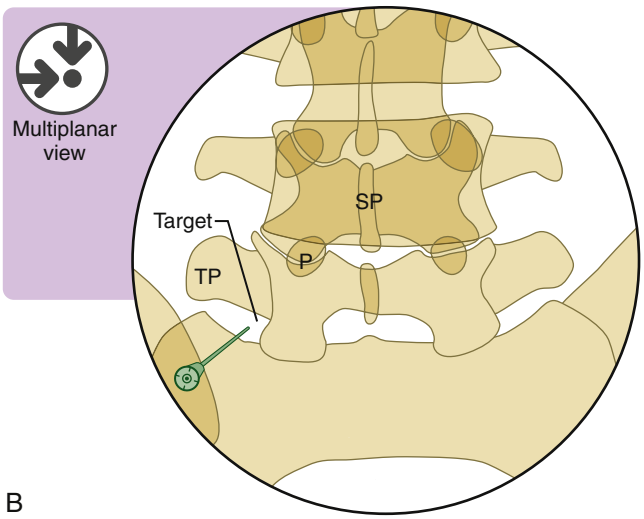
See Chapter 13D: Lumbar Transforaminal Epidural Steroid Injection—Needle Localization/Troubleshooting Diagrams.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (INTRODUCER NEEDLE PLACEMENT)

- **The SEP and inferior end plate (IEP) are optimized** by adjusting the cephalad or caudad tilt of the fluoroscopic beam. The spinous process is taken as the midline, and the pedicles are equidistant from the midline (see Chapter 3).
- **Advance the introducer needle** (Figs 13B.2A to 2C) to a point that it is both lateral and inferior to the pedicle.
  - It is important that the introducer does not pass beyond either of these two boundaries, so as to leave enough distance for the injection needle to properly pass into the foramen.
  - The goal of the target point of the introducer is to keep the introducer tip caudal, lateral, and dorsal to the final injection needle position.
- Once the introducer is at this target point, progress to Phase 2: Injection needle placement.



A



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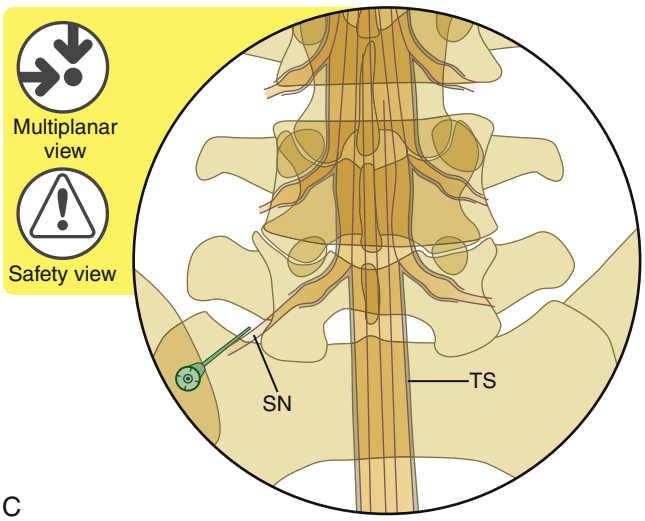

C

Anteroposterior View Safety Considerations (Introducer Needle Placement)

- Advance the introducer needle under the anteroposterior (AP) view to the above target.
- The needle should not go medially beyond the midpedicular line (the 6 o'clock position of the inferior aspect of the pedicle) to avoid dural puncture. SN and thecal sac (TS) lie medial to this point.

Fig. 13B.2. A, Fluoroscopic anteroposterior view with ideal introducer needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (INTRODUCER NEEDLE PLACEMENT)

- Confirm that the beam is perpendicular to the targeted spinal segment by optimizing SEP and IEP.
- Position the patient or fluoroscope (i.e., wig-wag).
- The introducer needle should be dorsal to the depth level of the most posterior aspect of the target neuroforamen (Figs 13B.3A to 3C).

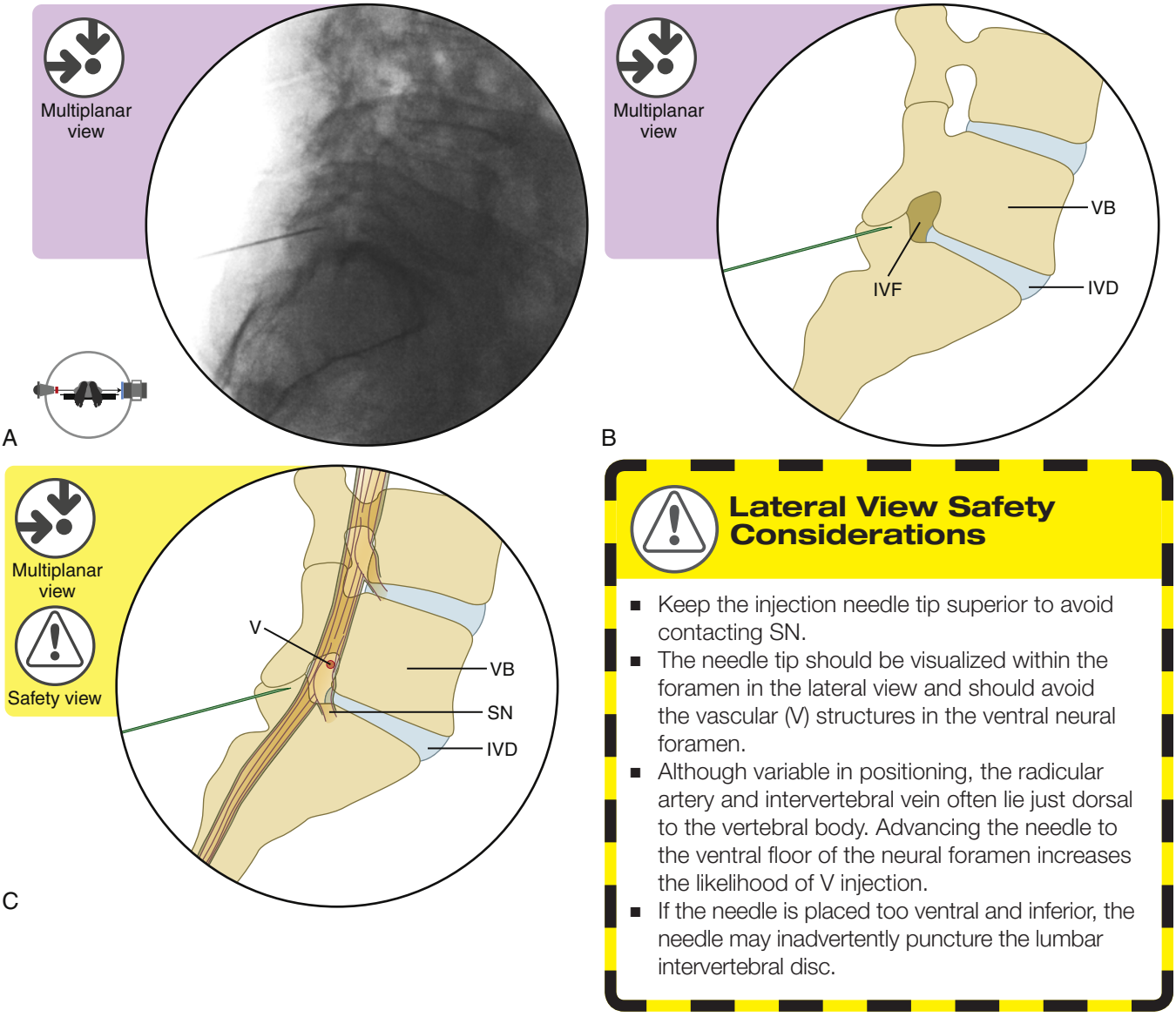
Multiplanar view
A
Multiplanar view
VB
IVF
IVD
B
Multiplanar view
Safety view
V
VB
SN
IVD
C
Lateral View Safety Considerations
Keep the injection needle tip superior to avoid contacting SN.
The needle tip should be visualized within the foramen in the lateral view and should avoid the vascular (V) structures in the ventral neural foramen.
Although variable in positioning, the radicular artery and intervertebral vein often lie just dorsal to the vertebral body. Advancing the needle to the ventral floor of the neural foramen increases the likelihood of V injection.
If the needle is placed too ventral and inferior, the needle may inadvertently puncture the lumbar intervertebral disc.

Fig. 13B.3. A, Fluoroscopic lateral view with ideal introducer needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Phase 2: Injection Needle Placement

Optimal Needle Position in Multiplanar Imaging (Injection Needle Placement)

Optimal Needle Positioning in the Anteroposterior View (Injection Needle Placement)

- **Bend the injection needle** with an appropriate curvature based on the approximated distance from the introducer tip laterally and dorsally to the final injection needle position. Refer to the curvature shown in Figs. 17B.3A to 3E. Use either an 18 G introducer and 22 G injection needle combination or a 20 G introducer and 25 G injection needle combination.
  - The more the bend, the less ventrally and more medially the injection needle will travel.
  - The less the bend, the more ventrally and less medially the injection needle will travel.
- **In AP view, place the injection needle through the introducer needle** until the tip just passes the bevel opening of the introducer needle. Check a spot film to assess the initial trajectory of the injection needle.
- **Adjust the injection needle trajectory** by rotating it within the introducer, and drive superiorly and medially to the target position as described previously for the AP view in the single-needle supraneural approach (Figs. 13B.4A to 4C).
  - The tip of the injection needle should not go medially beyond the midpedicular line (6 o'clock position) to avoid dural puncture.

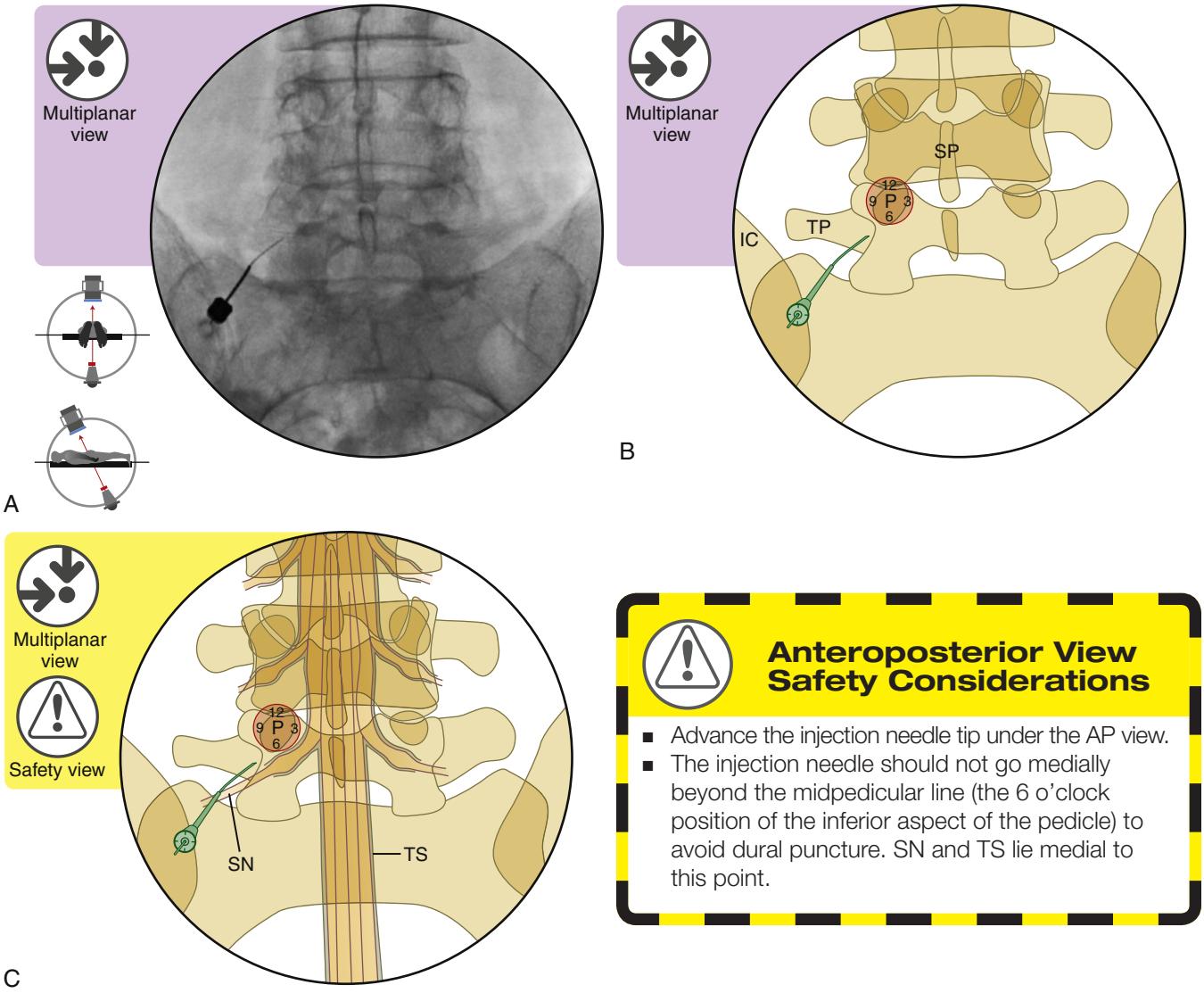

Fig. 13B.4. A, Fluoroscopic anteroposterior view with ideal injection needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

Optimal Needle Positioning in the Lateral View (Injection Needle Placement)

- Confirm a true lateral by optimizing the view of SEP and IEP. Adjust the patient or wig-wag the fluoroscope (Fig. 13A.3).
  - The target of the injection needle is the same as described previously for the lateral view in the single-needle supraneural approach (Figs. 13B.5A to 5C).
  - Avoid SN by staying superiorly.
  - **Adjust the cranial/caudal direction** by retracting the injection needle slightly, then rotating it *within* the introducer, and then driving in the desired direction.
  - Keep in mind the amount of bend that was imparted to the injection needle.
  - This is a confirmatory view. With this technique, the injection needle can deviate more medially than desired when advanced in the lateral view.
  - If significant ventral advancement is necessary, retract the injection needle and advance the introducer, then re-advance the injection needle.
- If the needle is advanced or withdrawn in the lateral view, another AP view should be obtained to confirm that the needle did not advance medial to the 6 o'clock position under the pedicle.

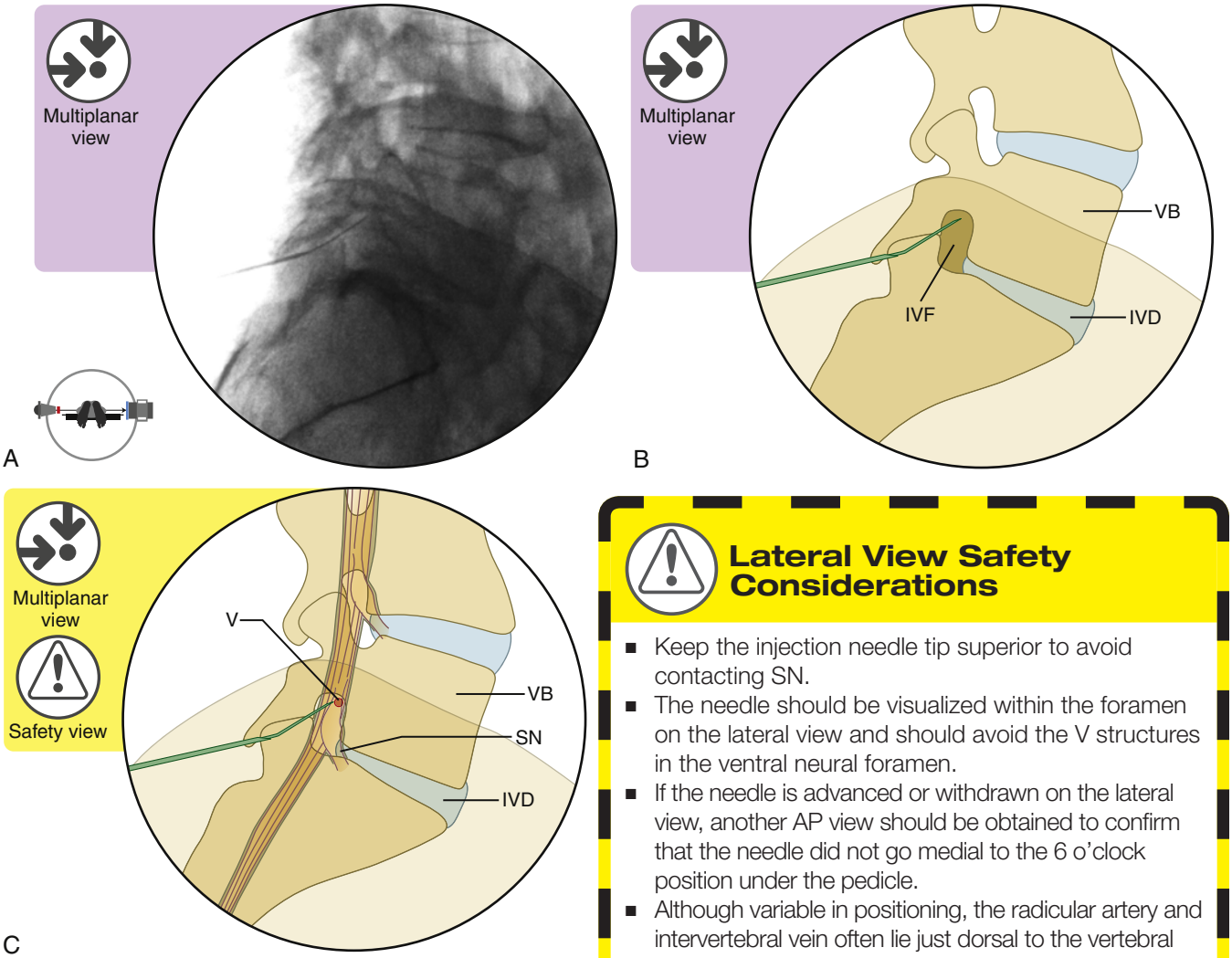

Fig. 13B.5. A, Fluoroscopic lateral view with ideal injection needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Lateral View Safety Considerations

- Keep the injection needle tip superior to avoid contacting SN.
- The needle should be visualized within the foramen on the lateral view and should avoid the V structures in the ventral neural foramen.
- If the needle is advanced or withdrawn on the lateral view, another AP view should be obtained to confirm that the needle did not go medial to the 6 o'clock position under the pedicle.
- Although variable in positioning, the radicular artery and intervertebral vein often lie just dorsal to the vertebral body. Advancing the needle to the ventral floor of the neural foramen increases the likelihood of V injection.
- If the needle is placed too ventral and inferior, the needle may inadvertently puncture the lumbar intervertebral disc (IVD).

Optimal Images (Figs. 13.6 to 13.8)

- Ideal flow should outline SN and nerve root sheath and then flow into the epidural space medial to the pedicle to the suspected site of pathology.

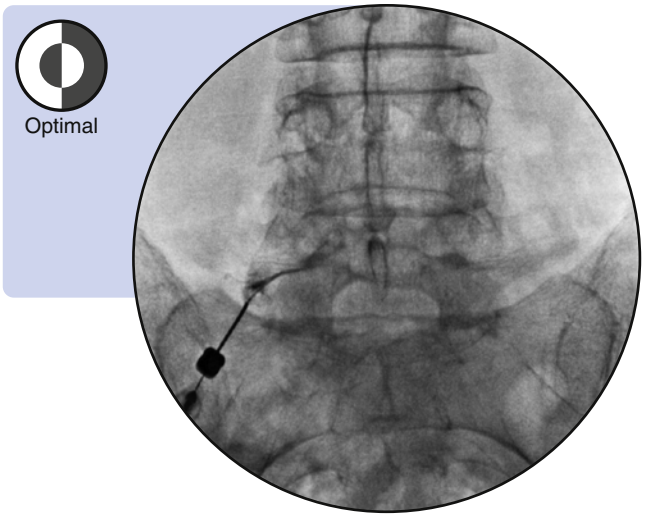

Fig. 13B.6. Anteroposterior fluoroscopic image of a left L5 transforaminal epidural steroid injection with 1 ml of contrast medium.

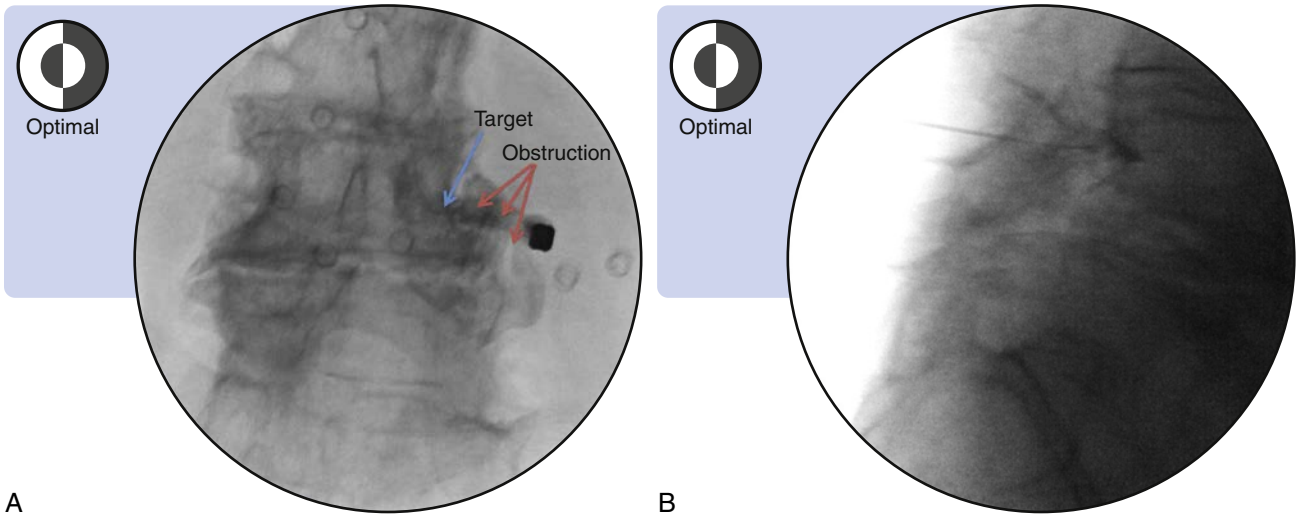

Fig. 13B.7. A, Anteroposterior fluoroscopic image of a right L4 transforaminal epidural steroid injection with 1.0 ml of contrast medium. The blue arrow shows the target needle position at the 6-o'clock position under the pedicle. The red arrows outline the superolateral margins of a large right L4-L5 zygapophyseal joint osteophyte obstructing the path of a standard oblique single-needle approach. **B,** Lateral fluoroscopic image of the same injection postcontrast.

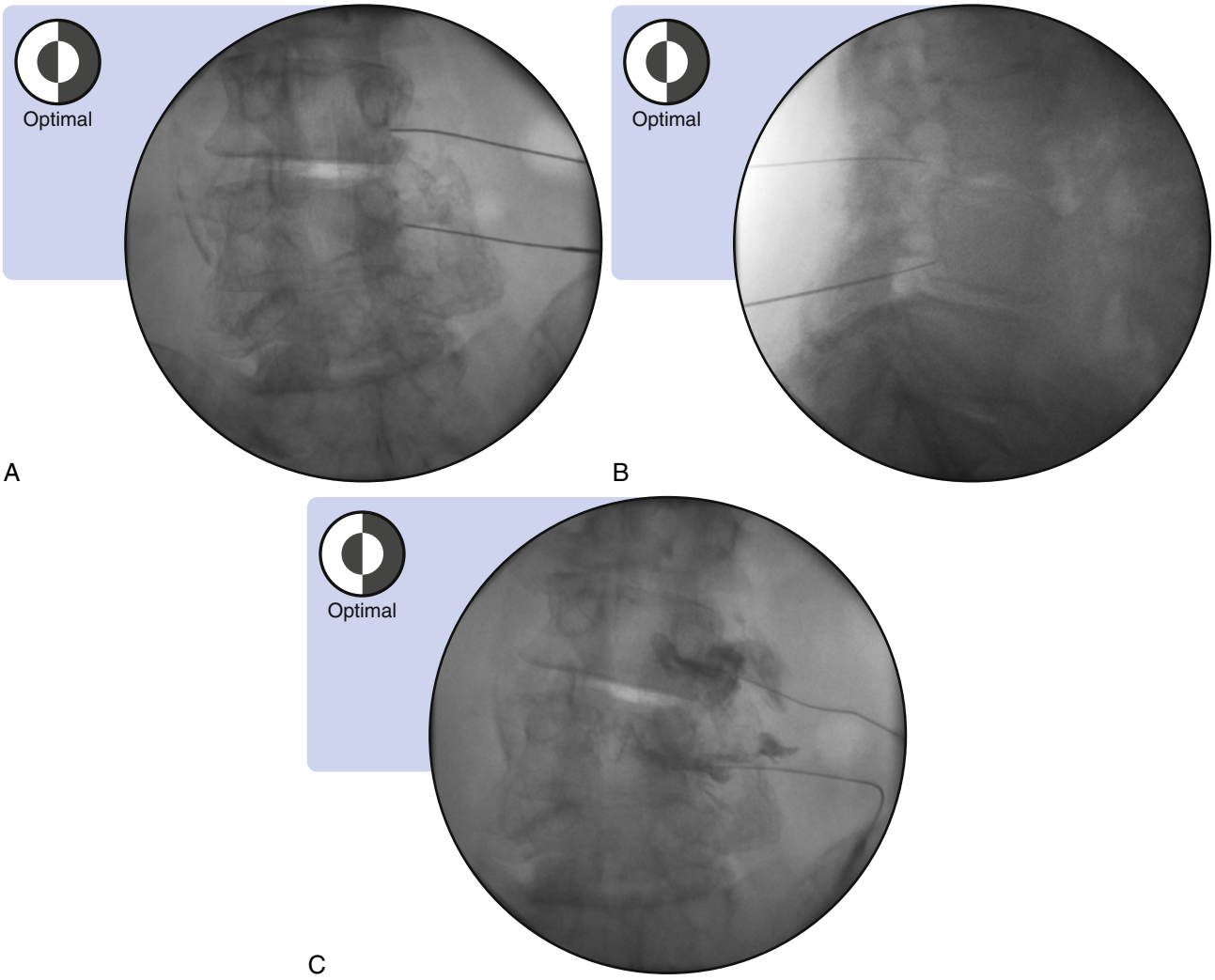

Fig. 13B.8. L4 transforaminal epidural steroid injection (TF-ESI) using the two-needle technique. At the L4 level, there is a large right-sided fusion mass, and the two-needle technique has been used to navigate the injection needle tip medial to the bony obstacle. **A,** Anteroposterior fluoroscopic view. **B,** Lateral fluoroscopic view. Note that the injection needle has passed anterior to the fusion mass. **C,** Postinjection anteroposterior fluoroscopic view demonstrating successful contrast flow medial and cephalad to the pedicle. A single-needle technique has been used for the L3 TF-ESI.

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CHAPTER 13C

Lumbar Transforaminal Epidural Steroid Injection—Infraneural Approach: Fluoroscopic Guidance

Christopher Bednarek, Justin J. Petrolla, and Michael B. Furman

INFRANEURAL APPROACH

Some authors suggest that transformainal epidural steroid injection needle placement infraneurally, in the inferior aspect of the foramen (i.e., Kambin's triangle,), is a theoretically safer approach, as the probability of encountering the radicular artery in the inferior foramen may be less likely. However, vascularity has been shown in this region as well. This alternative transforaminal injection is called the infraneural technique (also known as retrodiscal or preganglionic) where the needle stays in the lower third of the foramen or "low in the hole."

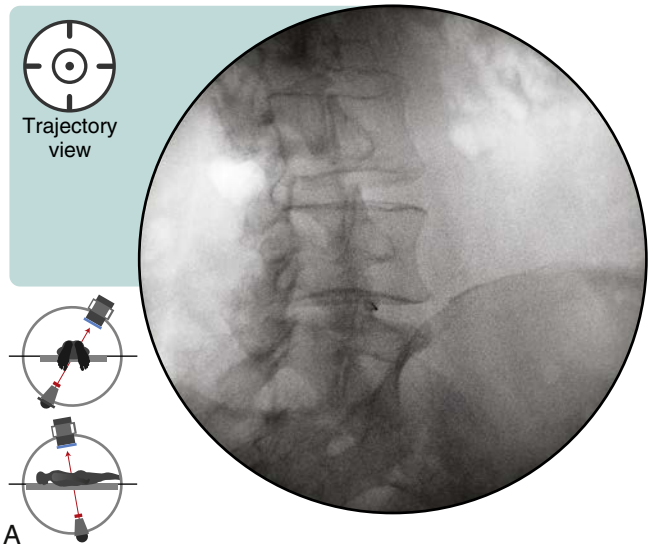
This technique may be used in place of the traditional supraneural technique or when anatomic changes compromise a safe injection. This technique has been described as retrodiscal because the needle is placed just posterior to the disc's posterior annulus; inadvertent disc injection is not uncommon due to close proximity to the disc. Some authors describe the infraneural approach as preganglionic because the needle tip lies proximal to the DRG along the transiting nerve root. The infraneural approach may be beneficial for injecting the nerve at the same disc level as a central herniation since injectate tends to flow along the nerve root as it transits inferiorly past a centrally herniated disc.

Of note, the initial trajectory of the infraneural injection is similar to the trajectory used in lumbar discography.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

- **Confirm the level** (with the use of the anteroposterior view) before obtaining the trajectory view.
- **Tilt the fluoroscope** to optimize end plate visualization.
  - A caudad or cephalad tilt is used to line up both the superior end plate (SEP) and inferior end plate (IEP) of the adjacent lumbar vertebrae. (Preferentially line up SEP inferior to the target.)
- **Oblique the fluoroscope** ipsilaterally (Fig. 13C.1):
  - The C-arm is then obliqued toward the symptomatic side so that the superior articular process (SAP) bisects the IEP of the superior vertebral body (VB). The target is the junction of SAP and SEP of the **inferior** VB.
  - This setup is similar to lumbosacral discography (see Chapter 17).
  - This is the trajectory view; needle entry should be parallel to the C-arm angle.



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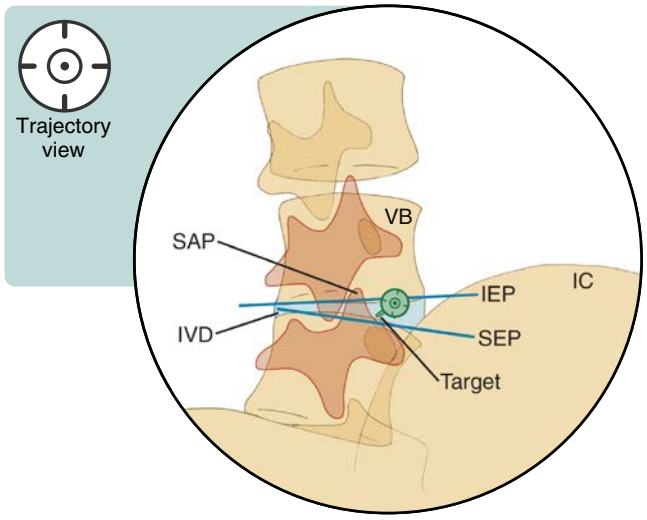

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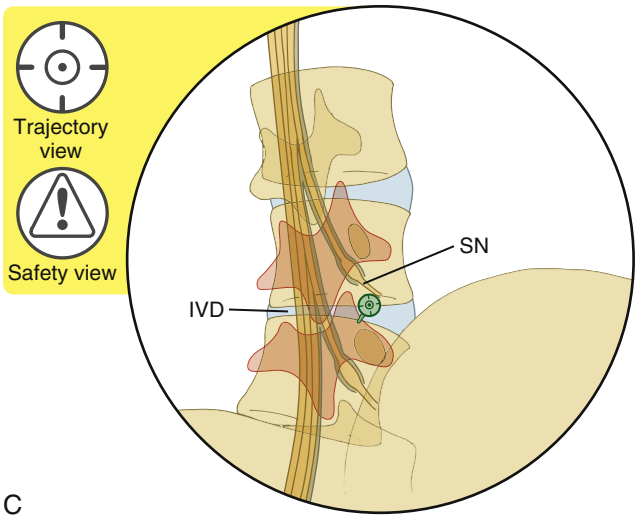


C

Notes on Positioning in the Trajectory View

- Maintain the needle in the lower third of the foramen or "low in the hole."
- This view is not optimal for visualizing an inadvertent disc injection. Alternate between anteroposterior and lateral views as the target position is approached.
- The needle may be placed as low as possible in the lower third of the foramen.

Trajectory View Safety Considerations

- Avoid the spinal nerve by staying inferior (i.e., in the lower third of the foramen).

Fig. 13C.1. A, Fluoroscopic image of trajectory view with needle in position. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Positioning for Multiplanar Imaging

See Chapter 13D: Lumbar Transforaminal Epidural Steroid Injection—Needle Localization/Troubleshooting Diagrams.

OPTIMAL NEEDLE POSITIONING FOR THE ANTEROPOSTERIOR VIEW (FIG. 13C.2)

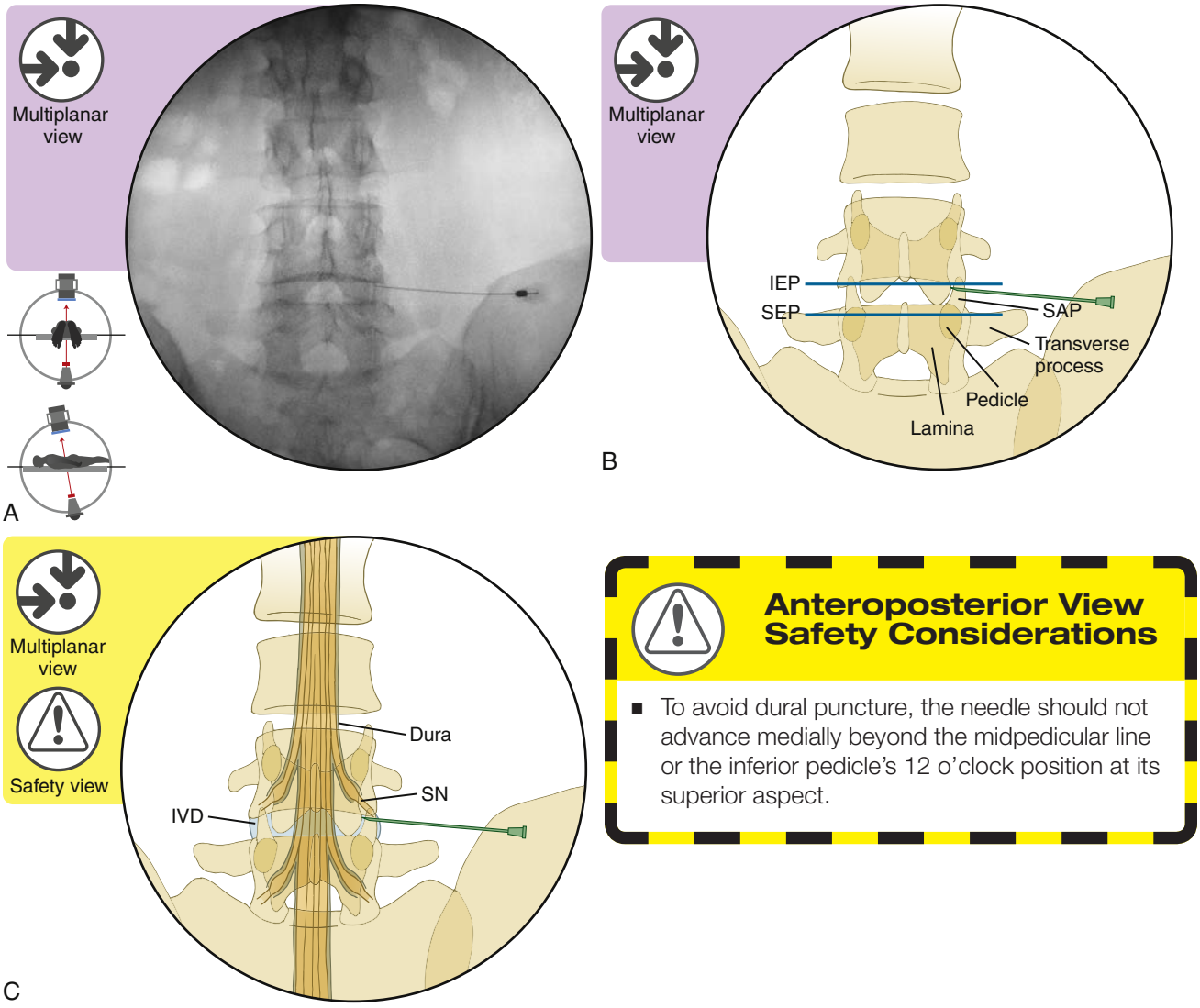
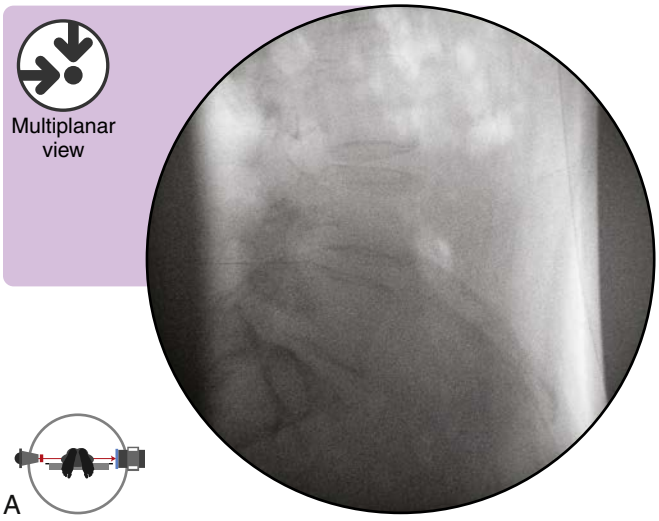


Fig. 13C.2. A, Fluoroscopic anteroposterior view with ideal needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

OPTIMAL NEEDLE POSITION FOR THE LATERAL VIEW (FIG. 13C.3)



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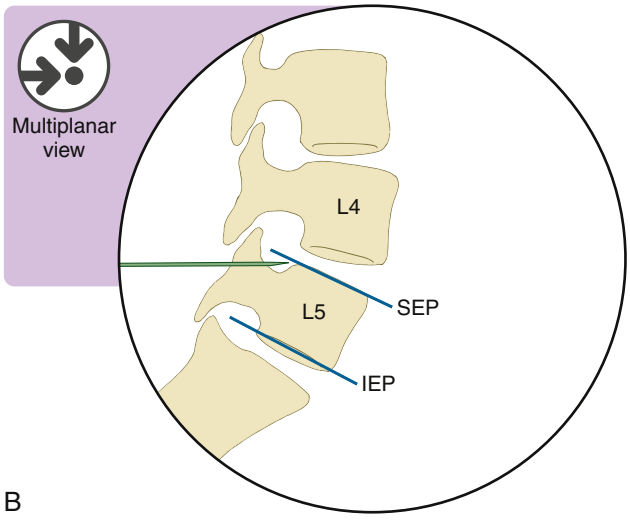

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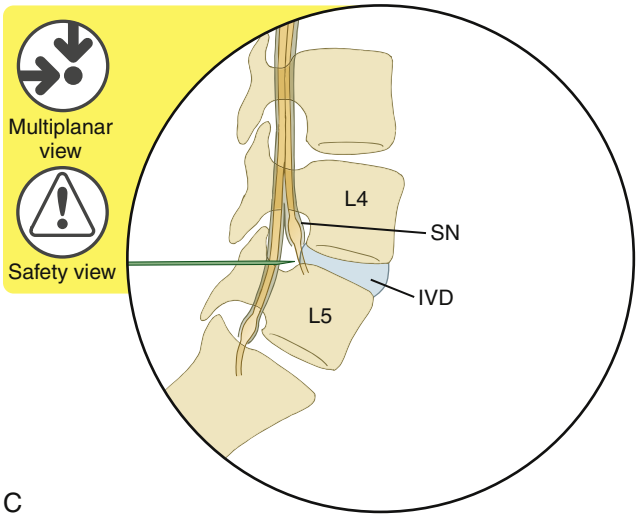


C

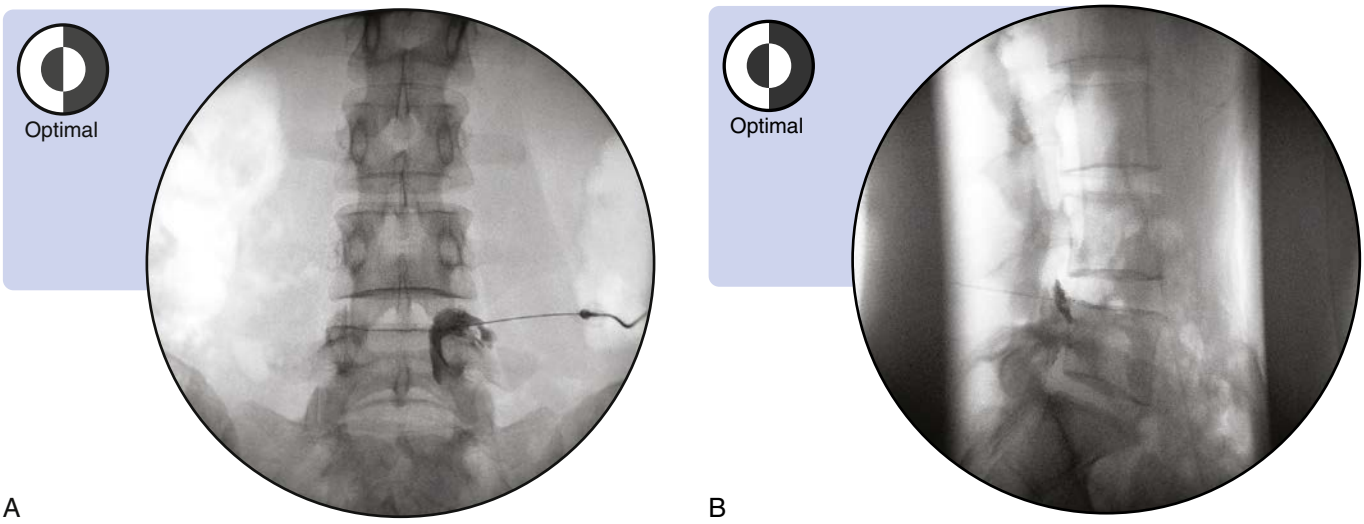
Lateral View Safety Considerations

- Avoid intervertebral disc entry by advancing the needle in the lateral view.
- Do not advance too far ventral where it may inadvertently puncture the lumbar intervertebral disc (see optimal Fig. 13C.8 and suboptimal Fig. 13C.10).

Fig. 13C.3. A, Fluoroscopic lateral view with ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images (Figs. 13C.4 to 13C.8)

Different optimal flow patterns may be observed.



A B

Fig. 13C.4. A, Anteroposterior fluoroscopic image of lumbar transforaminal injection with 1.5 cc of contrast medium, yielding a saddle-shaped contrast pattern. **B,** Lateral fluoroscopic image of lumbar transforaminal injection with 1.5 cc of contrast medium.

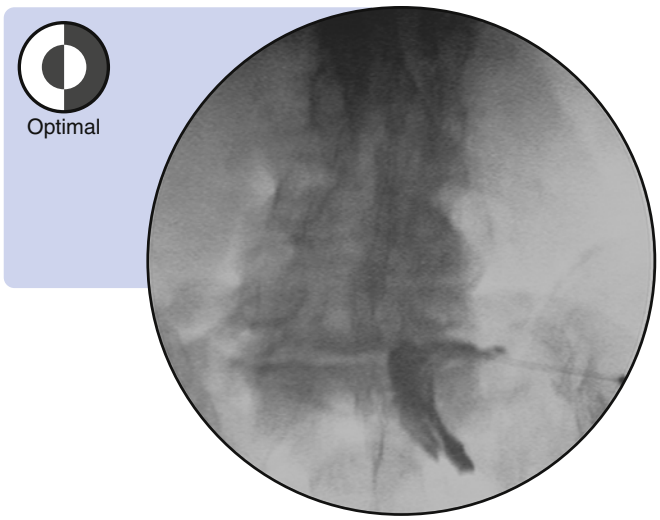


Fig. 13C.5. Optimal contrast pattern with flow medial to the pedicle. Often, the contrast extends inferiorly. Note that the injectate flows along the nerve as it transits inferomedially along the disc.

Optimal Image

- The infraneural approach is beneficial for getting injectate along the nerve as it transits inferomedially past a centrally herniated disc.
- There may be more posterior annular disc coverage but less foraminal coverage with this technique.[19]

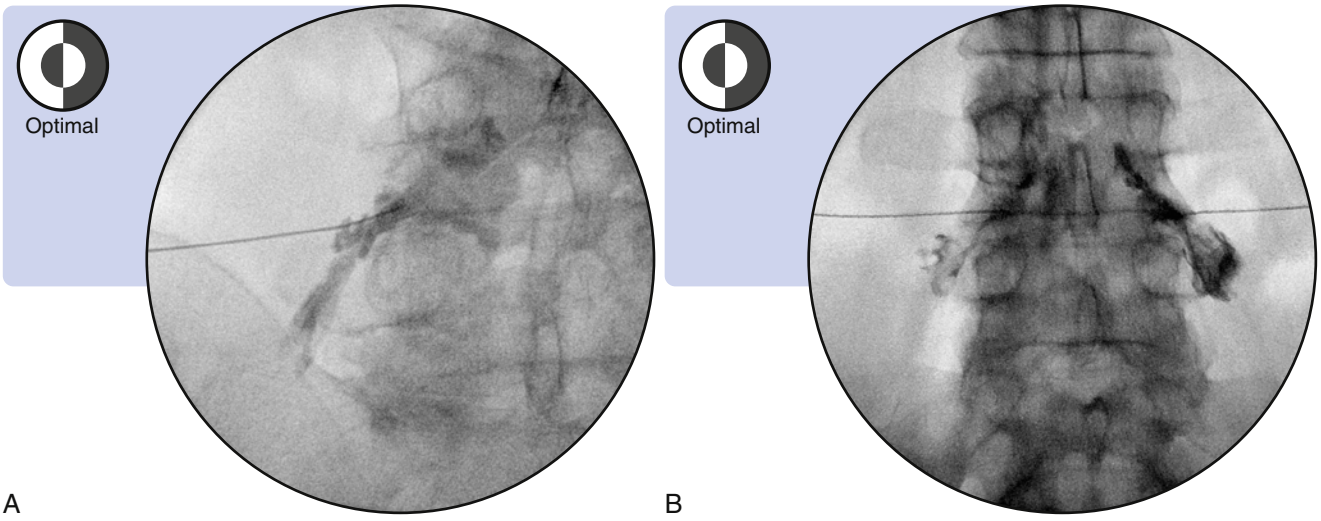


Fig. 13C.6. A, Left L4 transforaminal infraneural injection: fan-shaped contrast pattern. **B,** Bilateral L4 transforaminal infraneural injections: spread along the axillae of the nerve roots.

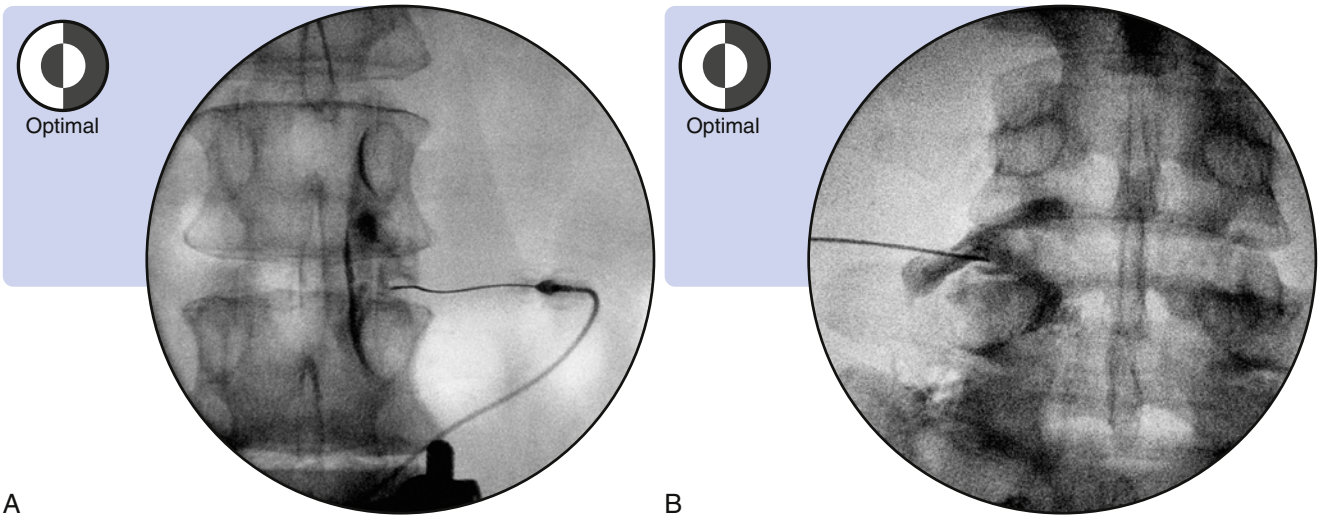


Fig. 13C.7. A, Right L3 transforaminal infraneural injection above an L5/S1 fusion: Linear lateral recess contrast spread outlining the exiting spinal nerves with superior and inferior flow. **B,** Left L4 transforaminal epidural injection: Combination of axillary and saddle-shaped contrast patterns.

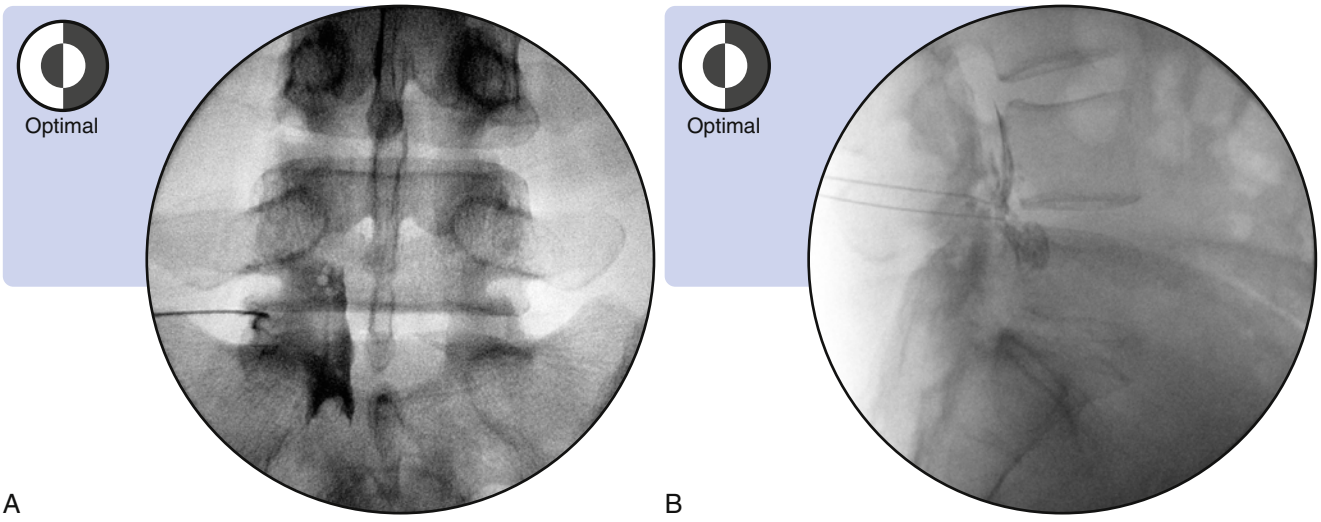


Fig. 13C.8. This contrast flow pattern outlines the disc posteriorly into the epidural space. **A,** Anteroposterior view of left L5 transforaminal infraneural injection. **B,** Lateral view in the same patient with a second needle placed for a bilateral L5 transforaminal infraneural injection (lumbarized S1). Note in **B** how the disc can extend posteriorly beyond the dorsal vertebral bodies. If the needle had been placed more ventrally, an intradiscal injection would be more likely (see suboptimal Fig. 13.10A and B).

Suboptimal Images (Fig. 13C.9 and 13C.10)

Suggestions to avoid an inadvertent, suboptimal, intradiscal injection:

1. Review preoperative parasagittal images to determine whether there is a foraminal disc protrusion inferiorly.
2. Correlate the sagittal MRI or CT with the fluoroscopic lateral images to estimate the disc location posteriorly, and avoid venturing too ventrally into the disc.
3. Be sure you have a true fluoroscopic lateral (see Chapter 3). Otherwise, you may underestimate the true needle tip depth.
4. Monitor the resistance to needle advancement and/or injection. Resistance to needle advancement across the inferior aspect of the foramen is either due to the annulus or tangential passage along SAP.

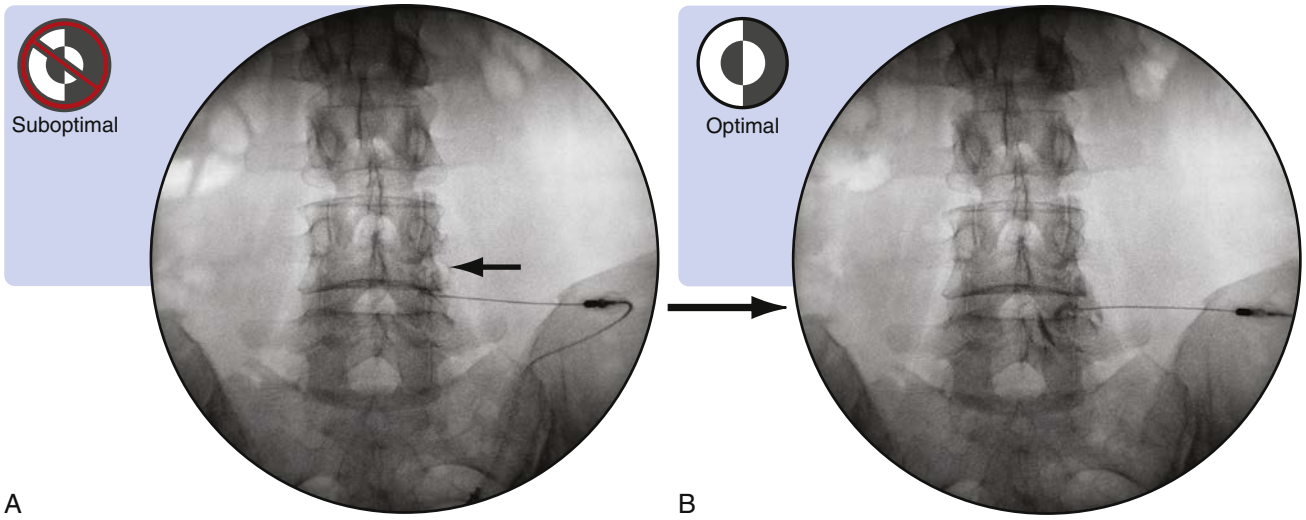


Fig. 13C.9. A, Anteroposterior fluoroscopic image with vascular uptake (arrow). **B,** Anteroposterior fluoroscopic image with a repositioned needle now seen with optimal contrast flow.

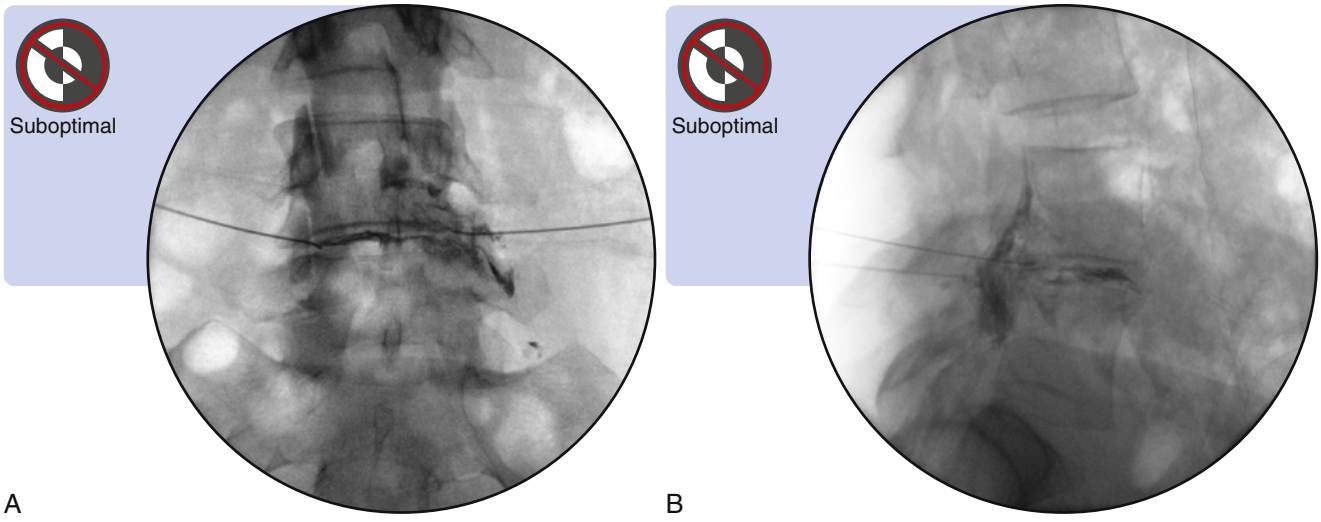


Fig. 13C.10. A, Discs may be further posterior than expected (see optimal Fig. 13C.8). Anteroposterior fluoroscopic image with inadvertent intradiscal injection of contrast medium. **B,** Lateral fluoroscopic image with inadvertent intradiscal injection of contrast medium.

Suggested Readings

Jasper JF. Lumbar retrodiscal transforaminal injection. *Pain Physician*. 2007;10(3):501–510.

Lee JW, Kim SH, Choi JY, et al. Transforiminal spidural steroid injection for lumbosacral radiculopat;hy: preganglionic versus conventional approach. *KOrean J Radiol*. 2006;7(2):139–144.

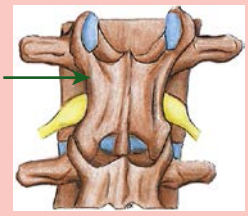
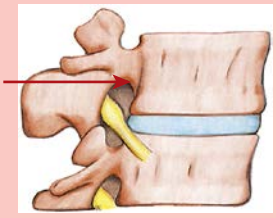
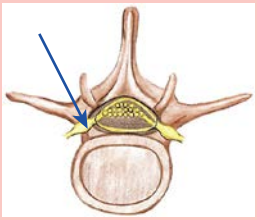
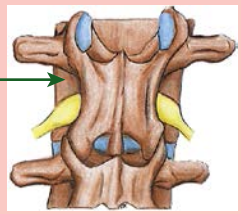
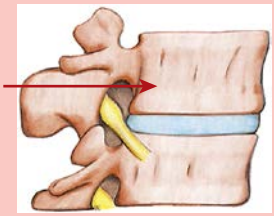
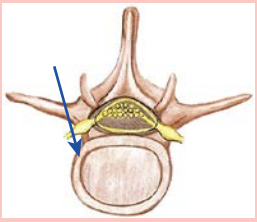
Jeong HS, Lee JW, Kim SH, et al. Effectiveness of transforaminal epidural steroid injection by using a preganglionic approach: a prospective randomized controlled studyl Radiology 2007;245(2):584–590.

CHAPTER 13D

Lumbar Transforaminal Epidural Steroid Injection: Needle Localization Diagram

Luis Baez-Cabrera and Michael B. Furman

Using anteroposterior and lateral fluoroscopic views to triangulate/calculate the axial needle tip position, with associated corrections and clinical pearls. These diagrams demonstrate supraneural needle placement. However, the concepts are similarly applied to the infraneural/retrodiscal approach.

	Anteroposterior(AP) View: Green arrow location determines Right/Left needle tip position	**Lateral View: Red arrow location determines Anterior/Posterior needle tip position**	**Calculated Axial View: Blue arrow indicates needle tip position in the prone patient**	**Correction/Clinical Pearls**
Orientation	Left Right	Posterior Anterior	Left Right	
Optimal approach	Tip at 6 o'clock of pedicle 	Tip is superior in the foramen, not quite touching the vertebral body 		Optimal position; no adjustment needed.
Scenario A Needle too ventral, not medial enough	Tip not medial enough 	Tip is advanced too far ventral 	Needle is noted to be at the posterior and lateral aspects of the vertebral body. 	Needle needs to be more medial in the anteroposterior view. Initial setup was not oblique enough. Check multiplanar imaging frequently. Start over or retrieve the needle and aim more medial.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

	Anteroposterior(AP) View: Green arrow location determines Right/Left needle tip position	**Lateral View: Red arrow location determines Anterior/Posterior needle tip position**	**Calculated Axial View: Blue arrow indicates needle tip position in the prone patient**	**Correction/Clinical Pearls**
Orientation	Left Right	Posterior Anterior	Left Right	
Scenario B Needle too medial and not ventral enough		Common mistake—cannot advance due to the approaching periosteum	Needle is noted to be in the bony posterior elements.	Trajectory needs to be less medial and more ventral. Initial setup was too oblique. Check multiplanar imaging frequently. Start over or retrieve the needle and aim less medial and more ventral.
Scenario C Needle too medial and not ventral enough (more ventral than above)			Needle is approaching the spinal canal, too medial too soon.	Advancing more medial may violate the thecal sac. Initial setup was too oblique. Trajectory needs to be less medial. Check multiplanar imaging frequently. Start over or retrieve the needle and aim less medial.
Scenario D Needle is too far ventral		Tip is advanced too far ventral	Needle is noted lateral to the vertebral body and anterior to the neural foramen.	Initial setup was not oblique enough. Check multiplanar imaging frequently. Start over or retrieve the needle and aim more medial and less ventral.

CHAPTER 14

Lumbar Myelography

Sarah E. Hagerty, Brian D. Steinmetz, and Michael B. Furman

Lumbar myelography is a radiographic study that is used to evaluate central and neuroforaminal stenosis, bony lesions, and cord compression. It is also a fairly reliable alternative for patients who are unable to undergo magnetic resonance imaging (MRI). Although MRI is preferred for the evaluation of disc pathology, soft tissue, and neural compression, computed tomography (CT)-myelography remains an option for diagnostic testing. Metal from previous surgery or trauma may cause artifact on MRI imaging that may limit the image quality within the central spinal canal, which is better assessed and visualized with CT myelogram. CT enables better assessment of hardware, such as pedicle screws, to assess for osteolysis. In addition, CT-myelography is often used, and sometimes preferred, by surgeons as the diagnostic imaging study for preoperative planning.

Proper sterile precautions and techniques in performing myelography are essential to decrease adverse effects such as headache, hemorrhage, fever, meningitis, altered mental status, and seizures. The most common complication is spinal headache, ranging from 32% to 70% incidence, which may require intravenous hydration or a blood patch.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View: The Trajectory/ Anteroposterior View Is Also a Multiplanar View

- The patient should be in a prone position with pillows under the pelvis, the goal being to flatten the lumbar lordosis.
- **Review available studies to evaluate for stenosis, previous surgeries, and hardware so that a proper needle entry level can be chosen.**
- **Confirm the level** (under the anteroposterior [AP] view). It is preferable to enter below the conus, typically at the L2-L3 interspace or below. If an MRI is available, it can be useful to confirm the level. Because the target is the intrathecal space, the needle can often be introduced into the site of a previous laminectomy (unlike the strategy for a lumbar epidural injection).
- It is preferable to enter in the interspace at the vertebral body, rather than the disc space. If there is a significant herniated disc and/or central stenosis at the chosen interspace, the thecal sac is narrowed, making entry into the thecal space more difficult and causing pain to the patient (see Figs. 14.5 and 14.10).
- The image intensifier is tilted caudad or cephalad to open up the target interlaminar space and facilitate easier entry between the two adjacent laminae. Here we demonstrate minimal obliquity for entry. However, the image intensifier can be obliqued 5 to 10 degrees to the right or left for the initial trajectory view. The needle should be placed parallel to the fluoroscopic beam, and the needle should be advanced toward the midline (Fig. 14.1A).

Notes on Positioning in the Anteroposterior/Trajectory View

- In the setting of an intact lamina, the initial approach is either straight AP or slightly oblique, similar to that of an interlaminar epidural steroid injection.
- Because the contrast dye is denser than the cerebrospinal fluid (CSF), the Trendelenburg or reverse Trendelenburg position is utilized during the procedure so that the contrast dye is able to stay in the lumbar region or flow cephalad toward the cervical spine (see Fig. 14.7B), depending on the targeted segments to be imaged.
- A smaller bore spinal needle (22 or 25 G) is preferred to lower the risk of bleeding and postprocedural headache.
- Target over a vertebral body and NOT over an intervertebral disc space.
- If radicular paresthesias or pain are elicited during ventral advancement of the needle, the needle should be repositioned. However, a mild radicular pressure sensation is not unusual when contrast dye is administered.
- **The needle should be maintained midline in line with the vertebral body.**
- This view should be used only to assess the mediolateral and superoinferior needle position; it should not be used for any substantial ventral needle advancement.
- To help determine the depth of the needle, contralateral oblique and/or lateral views are obtained.

There are typically no other radiolucent structures that are safety considerations in this trajectory view aside from advancing the needle too far ventrally. Please use the other views for needle advancement to best visualize the corresponding landmarks.

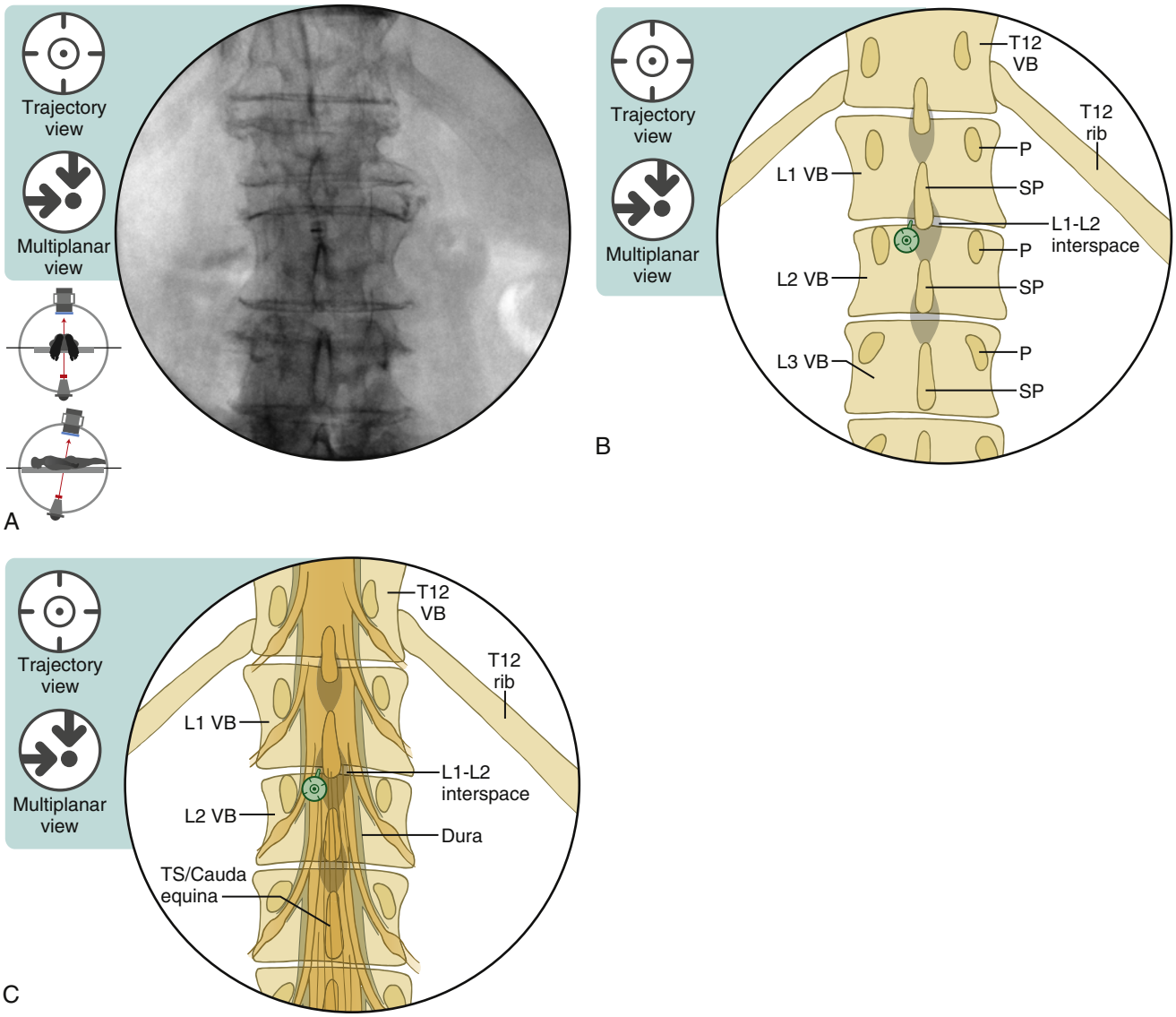


Fig. 14.1. A, Trajectory/anteroposterior (AP) view of the lumbar spine with the ideal needle position for L1-L2 interlaminar entry with a target that avoids the disc space. **B,** Radiopaque structures, AP/trajectory view. **C,** Radiolucent structures, AP/trajectory view.

OPTIMAL NEEDLE POSITION IN CONTRALATERAL OBLIQUE VIEW (FIG. 14.2)

The contralateral oblique view can be utilized similar to the interlaminar injection approach (see Chapter 12). For further information on the contralateral oblique view, see discussion in Chapter 3.

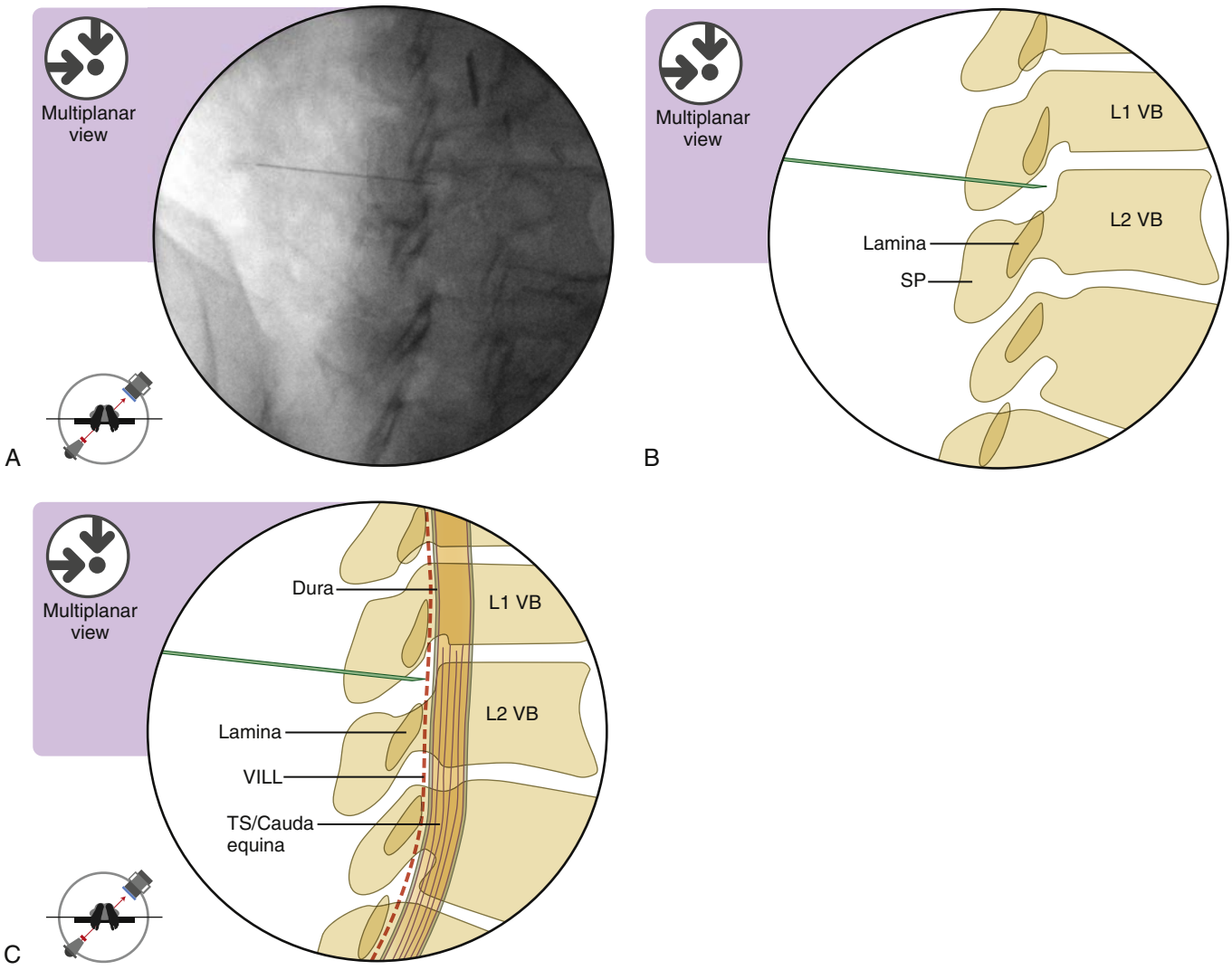


Fig. 14.2. A, Optional fluoroscopic contralateral oblique view of the lumbar spine with the ideal needle position. **B,** Radiopaque structures, oblique view. **C,** Radiolucent structures, oblique view.

OPTIMAL NEEDLE POSITION IN LATERAL VIEW (FIG. 14.3)

- The lateral view is the optimal view to visualize needle advancement. As you approach the dorsal central canal, the needle can be advanced while aspirating CSF between small needle advances.
- Once the needle is into the thecal sac, a nonionic iodinated contrast dye is slowly administered. Contrast dye outlines the spinal cord, nerve root bundles, and edges of the intervertebral discs.
- See Chapter 37 for **Omnipaque (Iohexol) adult intrathecal dosing guidelines.**

Notes on Optimal Needle Position in Lateral View

- Care should be taken to not inject air into the CSF.
- Once a myelogram pattern is demonstrated with contrast dye, patient positioning can be further adjusted into Trendelenburg or reverse Trendelenburg to optimize cephalad or caudal flow of contrast dye, respectively. The contrast dye is denser than the CSF, so will flow with gravity.
- The degree of cephalad and caudad dye flow will vary based on patient positioning and can be adjusted as needed.

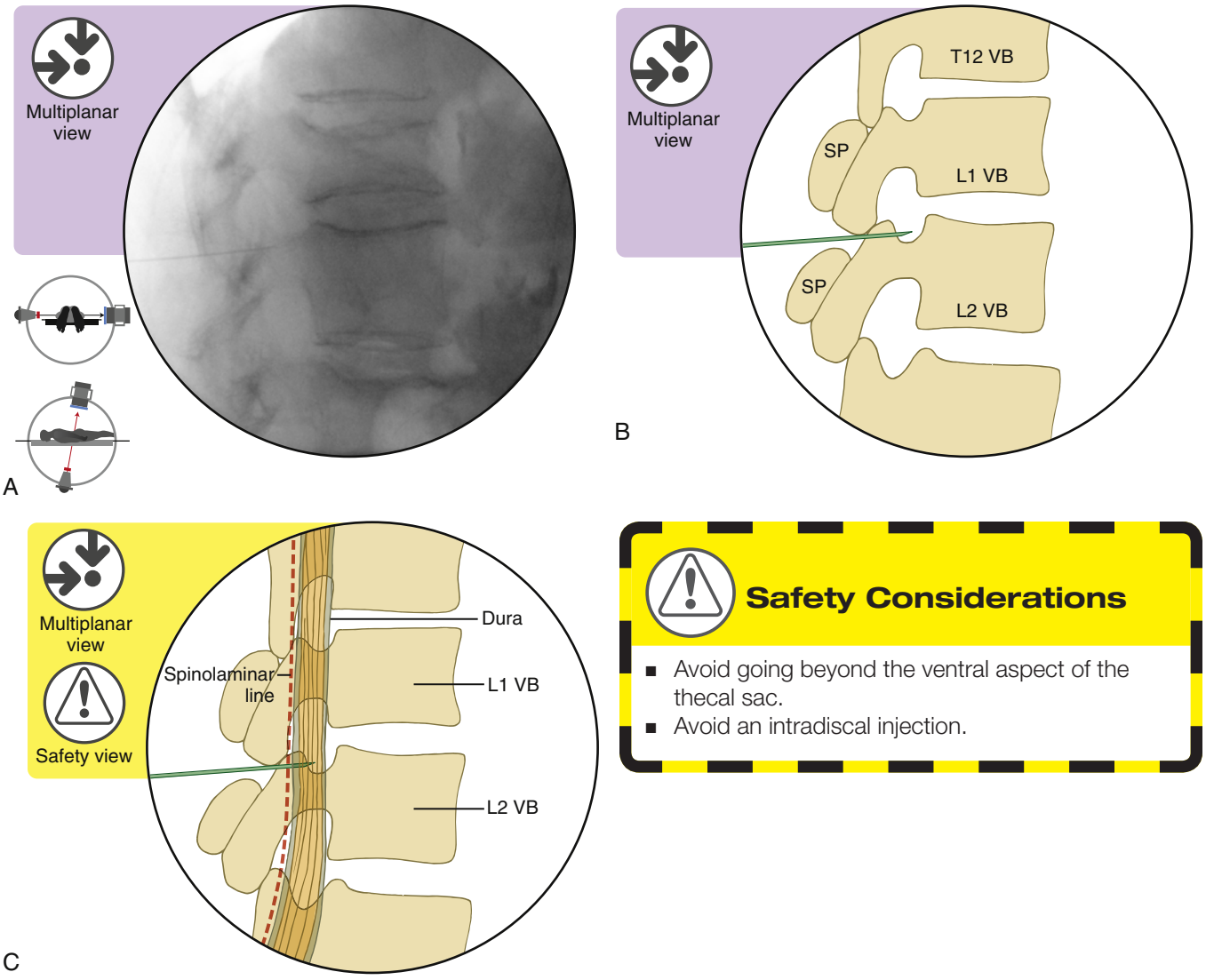


Fig. 14.3. A, Fluoroscopic lateral view of the lumbar spine. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images (Figs. 14.4 to 14.9)

- See Table 12.1 for contrast flow comparisons.
- Contrast dye outlines the spinal cord, nerve root bundles, and edges of the intervertebral discs.
- The AP view should show a "Christmas tree" pattern (Fig. 14.4). Maximum dosing of contrast dye is described and outlined in Chapter 8. There is typically a thin space between the lateral aspect of the outline of the thecal sac and pedicle, which represents the epidural space.
- With the patient lying prone, the contrast should lie ventrally in the thecal sac (Fig. 14.5).
- There should always be a thin epidural space without contrast between the ventral aspect of the outline of the thecal sac and vertebral bodies seen in the lateral view.
  There is also an advanced technique to enter at C1-C2, but this will not be discussed in this text.

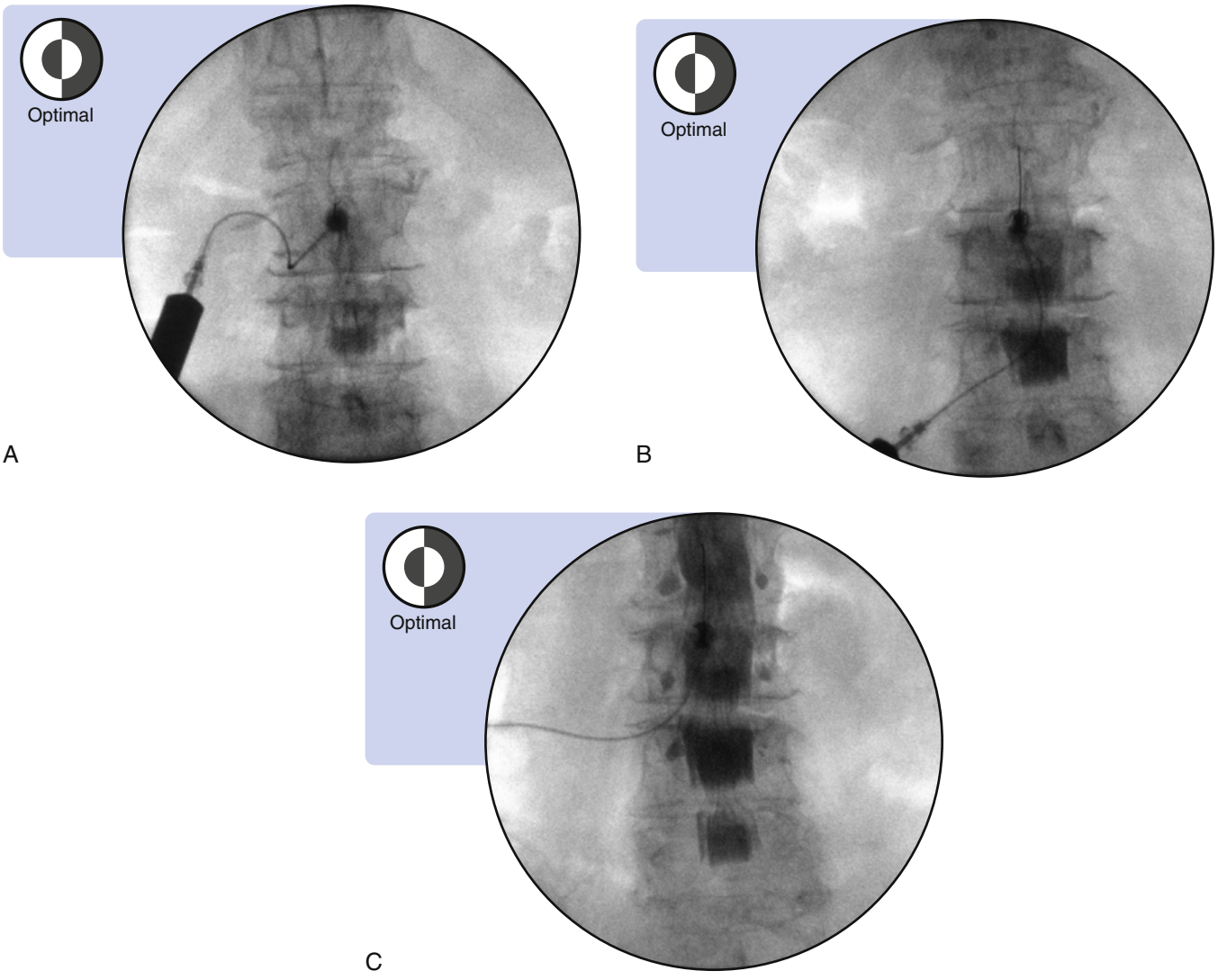
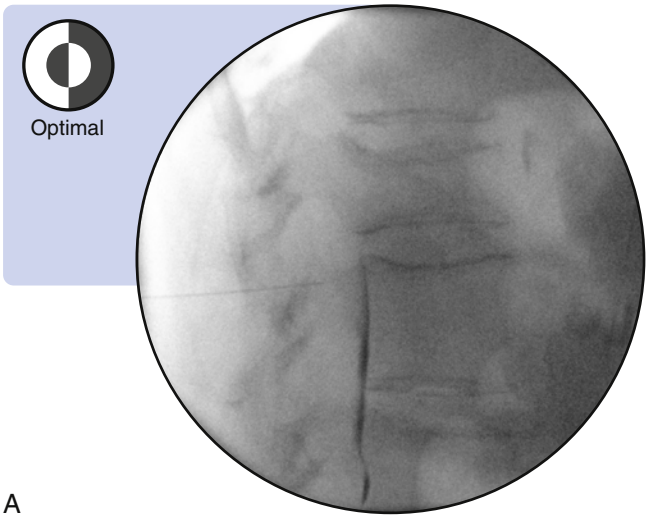


Fig. 14.4. Successive anteroposterior (AP) views of the lumbar spine with contrast flow in the thecal sac with typical diffuse "Christmas tree" pattern. **A,** Initial contrast flow in the thecal sac. **B,** Intermediate contrast dye flow pattern in the thecal sac. **C,** Advanced, thicker contrast dye flow pattern in the thecal sac. Typically, there should be a thin epidural space between the lateral aspect of the outline of the thecal sac and medial pedicle.



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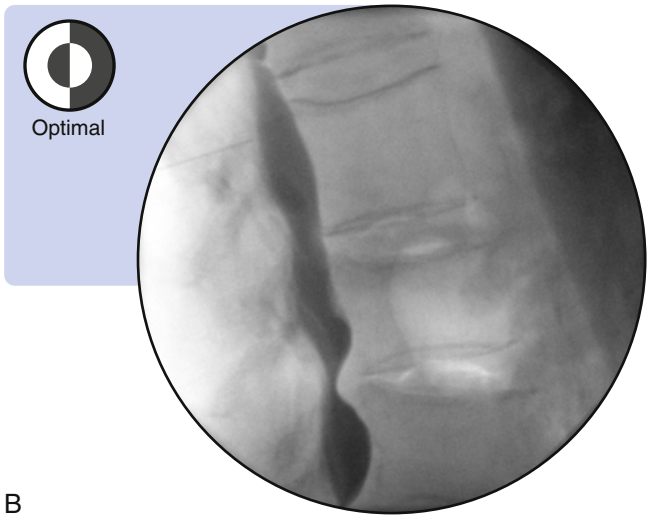

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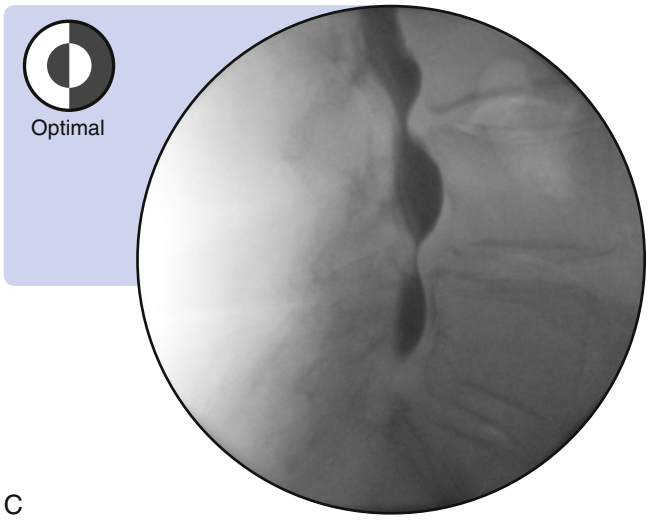


C

Fig. 14.5. Successive lateral views of the lumbar spine with contrast flow in the thecal sac. **A,** Confirmatory lateral view of the lumbar spine with initial contrast ventrally in the thecal sac. **B,** Higher volume of contrast dye ventrally seen in the thecal sac. Note the optimal needle position in line with the vertebral body instead of the intervertebral disc space. **C,** Confirmatory lateral view of the lumbar spine with higher volume of contrast dye ventrally seen in the thecal sac. Note how narrow the thecal sac can be when there is a herniated disc and/or spinal stenosis at the disc space. Note the distinct ventral margin of the dye gravitationally pooling along the ventral thecal sac in this prone patient and the hazy, more dorsal cerebrospinal fluid (CSF)-dye fluid-fluid interface. Note that there is a thin epidural space between the thick, dependent ventral aspect of the outline of the thecal sac and dorsal vertebral bodies.

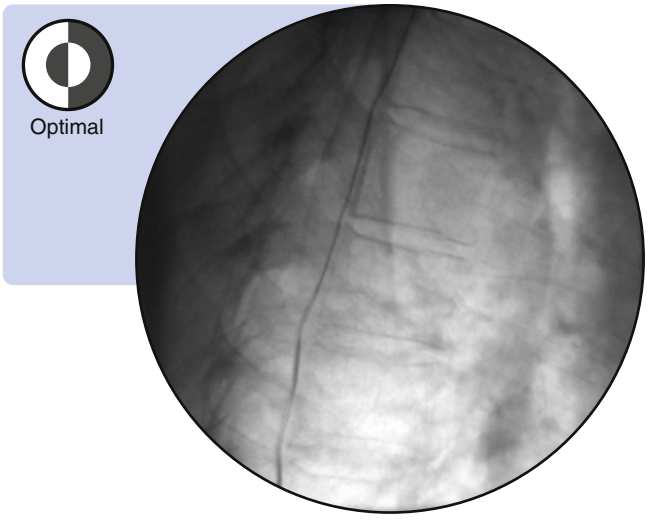


Fig. 14.6. Lateral view of the thoracic spine with contrast in the thecal sac. Note the thin space between the thick dye pattern and vertebral bodies, which represents the epidural space.

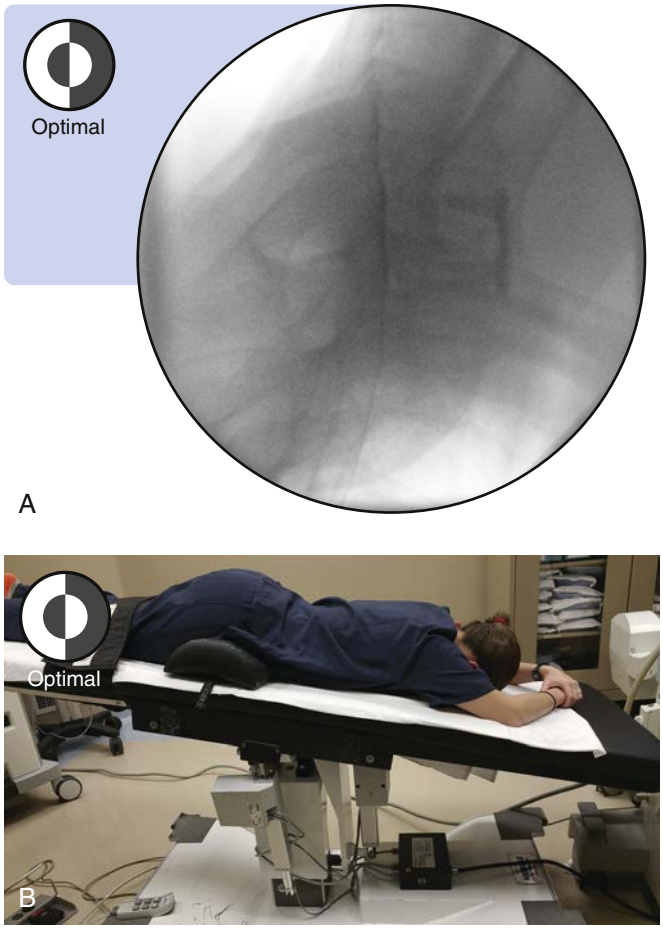


Fig. 14.7. A, Lateral view of the cervical spine with contrast in the thecal sac. **B,** Optimal positioning of the simulated patient for myelography to obtain cephalad flow to visualize contrast dye in thoracic or cervical spine for imaging. The contrast dye is denser than the cerebrospinal fluid (CSF), so will flow with gravity. For cervical and thoracic computed tomography (CT) imaging, it is optimal for the patient's hips to be above the thoracic apex (postcontrast injection) to aid in the cephalad flow of contrast media with gravity.

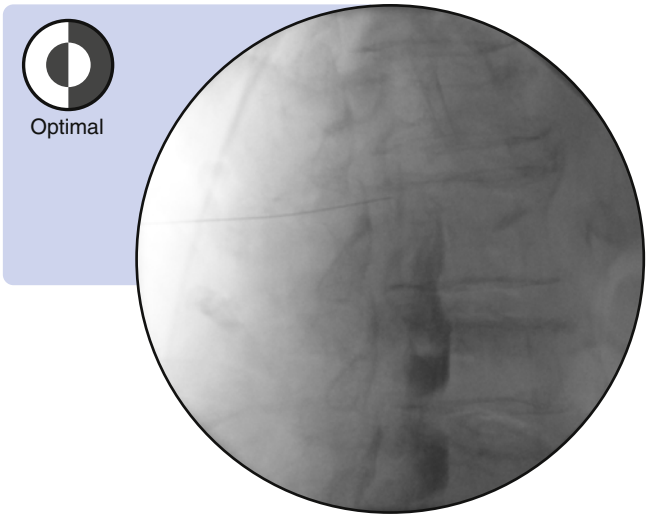


Fig. 14.8. Oblique view of the lumbar spine with contrast in the thecal sac.

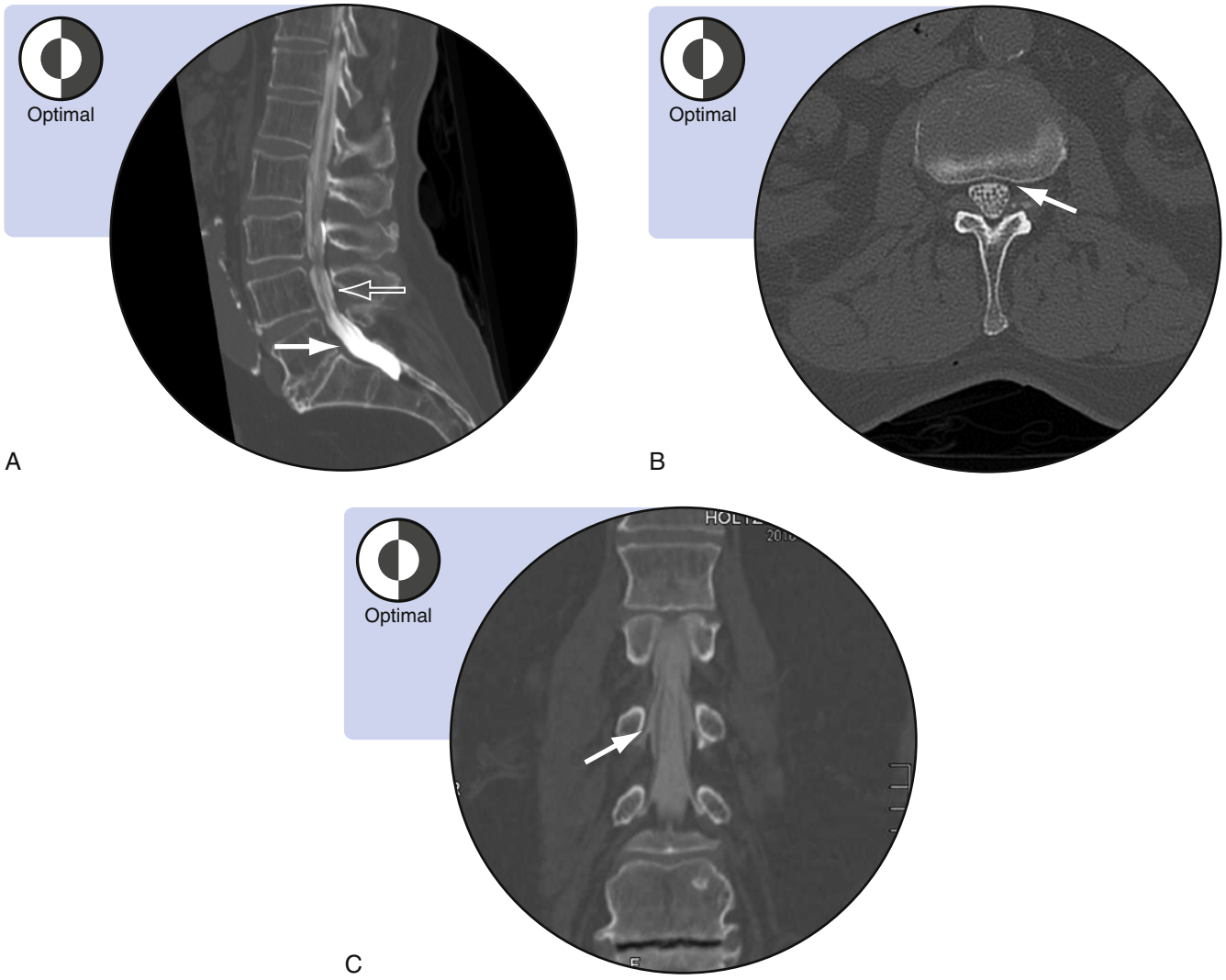
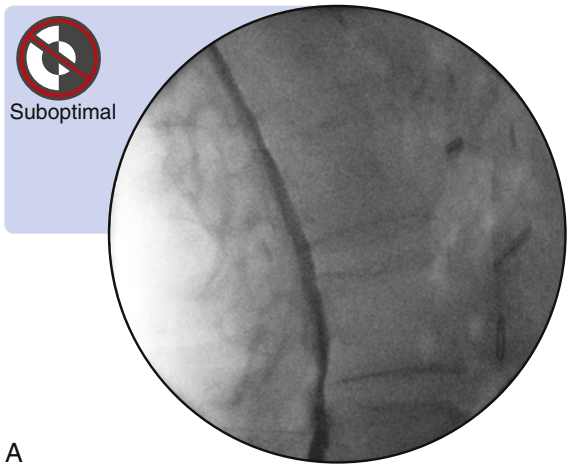


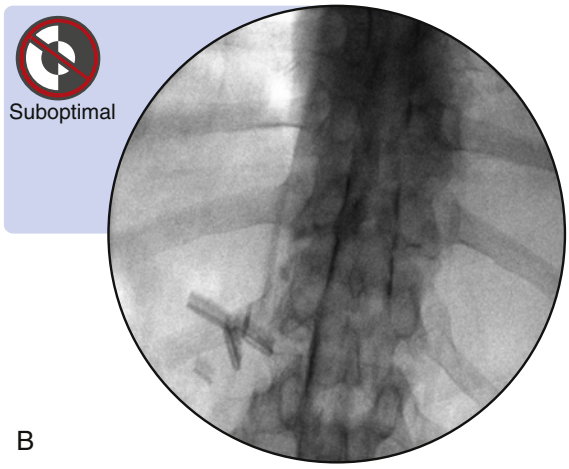
Fig. 14.9. Computed tomography (CT) images of an optimal myelogram **A,** Midline sagittal image. Note the thin epidural space with no contrast ventral (closed arrow) and dorsal (open arrow) to the thecal sac. **B,** Axial image. Note the intrathecal cauda equina and the thin epidural space with no contrast surrounding the thecal sac (arrow). **C,** Coronal image. Note the intrathecal contrast and the thin epidural space with no contrast between the thecal sac and medial pedicles (arrow). Compare these to Figs. 14.10C, D, and E.

Suboptimal Contrast Patterns (Figs. 14.10 and 14.11)

We demonstrate an inadvertent sdural boundry layer intradural/subdural injection (Fig. 14.10) and intradiscal injection (Fig. 14.11), which occurred during myelography. Compare the subdural injection to the above mentioned optimal intrathecal patterns. See Table 12.1 for further clarification about flow pattern expectations. See other **respective interlaminar and transforaminal epidural steroid injection chapters for epidural flow pattern comparison.**



A



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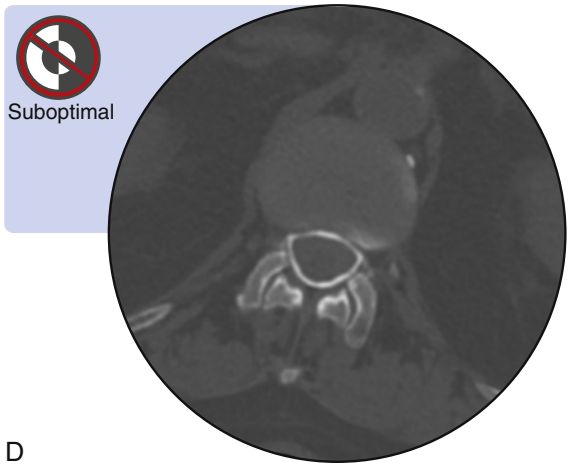
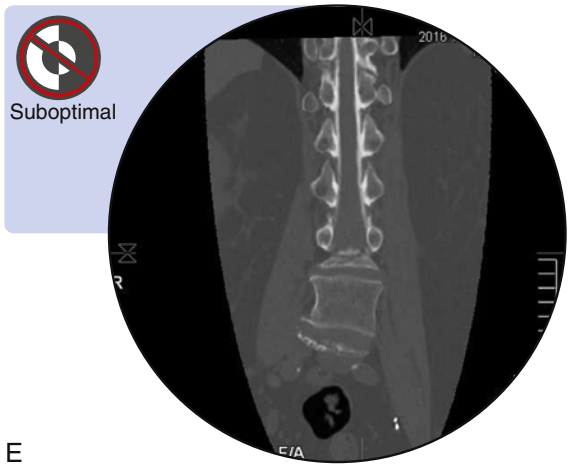


D



E

Fig. 14.10. Inadvertent dural boundry layer subdural/intradural contrast injection, which occurred during an attempted myelogram. The needle was advanced too far beyond the ventral margin of the thecal sac and 10 cc of Omnipaque 300 injected intradurally. Compare these images to the fluoroscopic myelogram images (Figs. 14.6 to 14.8) and computed tomography (CT)-myelogram images (Fig. 14.9). Note the thin, uniform, contrast-filled intradural space surrounding the thecal sac. **A,** Fluoroscopic lateral view of the lumbar spine with ventral subdural contrast. Note that the contrast is ventral in the canal, and there is no fluid-fluid interface ventrally as would be expected in a myelogram. **B,** Fluoroscopic anteroposterior (AP) view of the thoracic spine in the same patient with subdural/intradural contrast. Note the "tram track" appearance. Note the epidural contrast medially outlining the pedicles and the symmetric distribution. **C,** CT sagittal view of dural boundry cell layer intradural/subdural injection. The contrast is seen dorsally against the spinous process base along the spinolaminar line. Contrast is also seen ventrally with a thin epidural opening intermittantly seen between the contrast pattern and the vertebral bodies. **D,** CT axial view of a subdural injection. A contrast ring is seen outside the thecal sac and directly contacting the surrounding structures. **E,** CT coronal view of the same subdural/intradural injection, demonstrating the thin space surrounding the thecal sac with contrast approximating the medial pedicles with no flow out along the exiting spinal nerves.

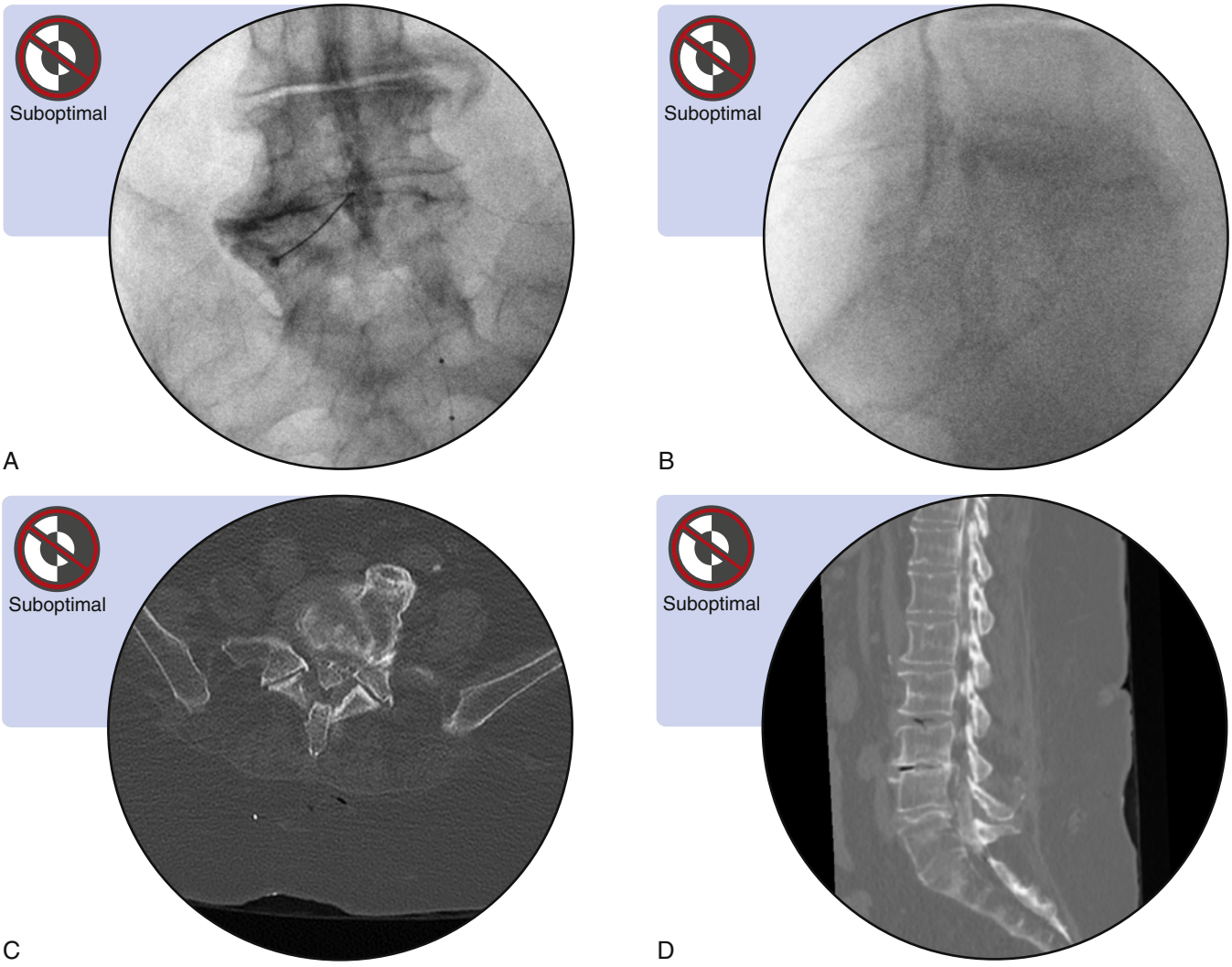


Fig. 14.11. Inadvertent intradiscal contrast injection during myelogram. **A,** Anteroposterior (AP) view of the lumbar spine with intradiscal contrast. Note that the needle enters over the interspace of the disc, rather than the interspace over the vertebral body. **B,** Lateral view of the lumbar spine in the same patient with intradiscal contrast. **C,** Computed tomography (CT) axial view of the myelogram. Note dye in the thecal sac and within the disc with ventral spread. **D,** CT sagittal view of the myelogram of the same patient with dye in the disc. This misadventure may have been avoided by using a needle trajectory which targeted over the vertebral body instead of the disc space.

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Suggested Readings

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CHAPTER 15

Lumbar Zygapophysial (Facet) Joint Procedures

The zygapophysial joints (Z-joints) in the spine are diarthrodial joints with articular facets that are covered with hyaline cartilage, enclosed by a capsule with synnvoium. The lumbar Z-joints derive their sensory innervation from two medial branches of the dorsal rami, with respect to pain: one from the dorsal ramus above and one at the same segmental level. In addition, the medial branch nerves are not named for the transverse process they cross but rather for their originating somatic nerves. For example, the L3 and L4 medial branches innervate the L4-L5 Z-joint. An exception to this convention is the L5-S1 Z-joint, which derives its sensory innervation through the L4 medial branch and L5 dorsal ramus. Please see Figs. 15E.1 and 15E.2 for more details regarding the Z-joint anatomy and innervation.

The lumbar zygapophysial (facet) joints were first recognized as a potential source of spinal pain by Goldthwait in 1911.[1] The term *facet syndrome* was first used by Ghormley in 1933.[2] Recent literature supports that the lumbar zygapophysial joints have a pain prevalence of 15% to 45% among individuals with chronic low back pain.[3-5]

Lumbar zygapophysial joint-mediated pain cannot be diagnosed with certainty by history, clinical examination, or radiographic imaging alone.[6-11] While intraarticular injection of the Z-joint may potentially provide diagnostic and therapeutic benefits, it has recently come under much scrutiny. Accessing the intraarticular joint space (Chapter 15A) remains an essential skill for the treatment of zygapophysial joint cysts via the intraarticular deposition of medication with or without attempts of aspiration or disruption.[12-18] Depending on the patient's clinical assessment, these injections can be performed unilaterally or bilaterally.

The lumbar medial branch block (Chapters 15B and 15D) is a purely diagnostic procedure, indicated to determine whether a patient's axial pain is caused by the zygapophysial joints under study. Lumbar MBBs provide superior diagnostic specificity compared to lumbar intraarticular zygapophysial joint injections. Lumbar zygapophysial joint diagnostic nerve blocks have been shown to be target specific, with defined needle trajectories and target points.[19] Depending on the patient's clinical assessment, these injections can be performed unilaterally or bilaterally.

Lumbar radiofrequency neurotomy (Chapter 15C) is typically performed after significant pain relief is reported following diagostic lumbar medial branch blocks. However, the approach to lumbar radiofrequency neurotomy is different from those used in the above mentioned injections. In addition, no contrast dye is necessary. The electrode is positioned to lie parallel and over the medial branch nerve. Because there is an anatomic variation in the course of the medial branch nerve, many practitioners perform, at a minimum, two lesions at each nerve level.[20]

Please see Chapter 15E for Anatomy, Dissections, and Lesion Zone Diagrams.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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CHAPTER 15A

Lumbar Zygapophysial Intraarticular Joint Injection—Posterior Approach: Fluoroscopic Guidance

Thomas S. Lee and Michael B. Furman

In this chapter, the approach described for zygapophysial joint (Z-joint) intraarticular injection involves the use of a trajectory view in an oblique orientation and advancement involving the use of a minimum of two views: anteroposterior and oblique. The use of a lateral view is also recommended for final confirmation, especially when the superior recess needs to be accessed. Inferior recess access will also be described.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

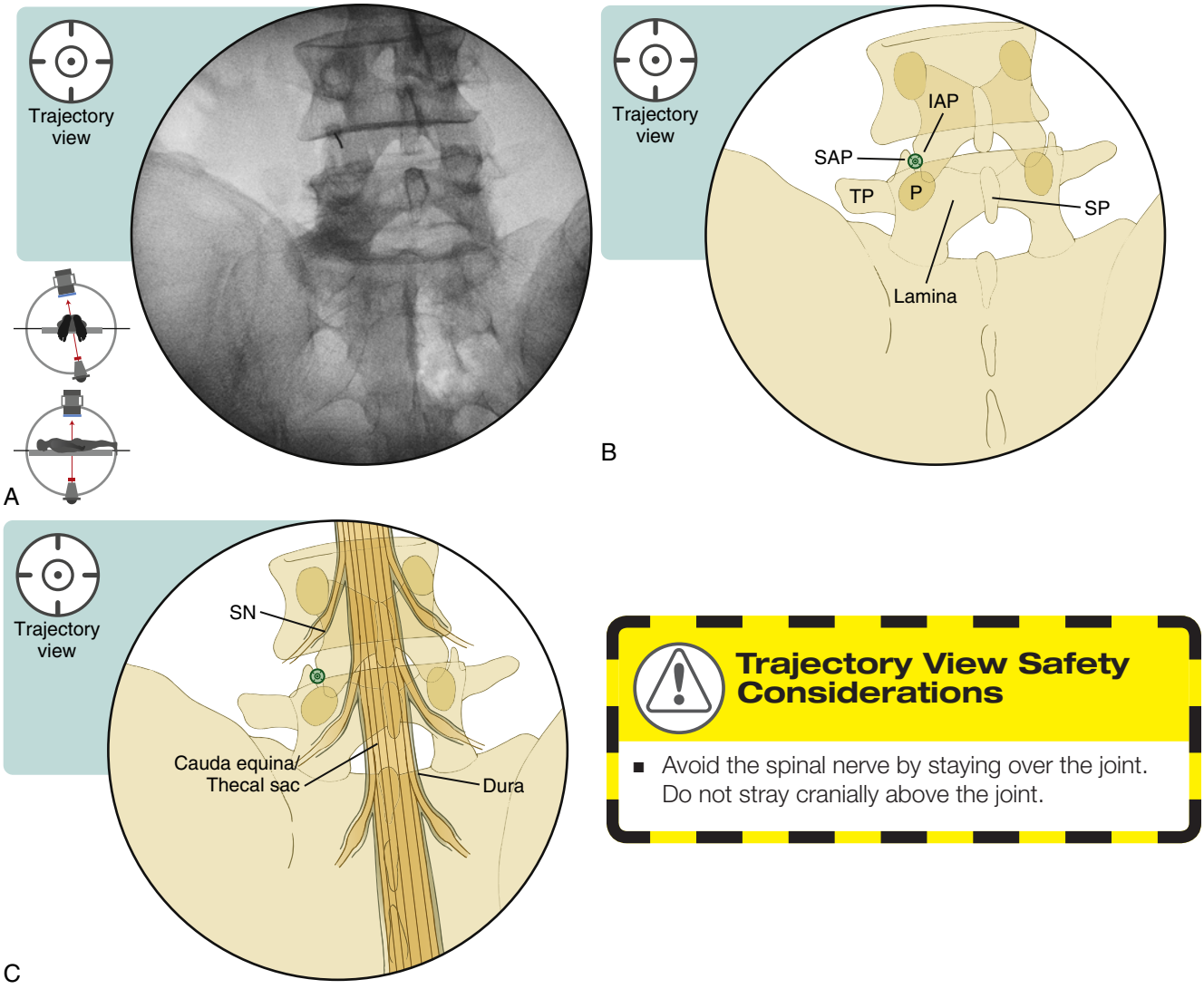
Confirm the level (with the anteroposterior view).
Oblique the fluoroscope's image intensifier ipsilaterally (Fig. 15A.1).

- If the joint is sagittally oriented, oblique angulation of the fluoroscope may not be necessary.
- Correlation with magnetic resonance images or computed tomography axial images may be helpful for estimating the optimal oblique angle at which the joint may be entered. As described by Horwitz and Smith, the zygapophysial joints (Z-joint) can have a flat or curved shape in the transverse plane and can be symmetric or asymmetric at the same level (Fig. 15A.2A, B).
- The target needle destination is the middle to upper half of the joint and toward the medial border of the joint space silhouette. The superior or inferior recess can be the target too, which is discussed later in the chapter.
- Oblique ipsilaterally until the joint space silhouette can be identified, and then slightly decrease the angulation, usually 5 to 10 degrees, until the silhouette begins to fade away.
  - This optimizes access to the medial border of the joint by making use of a more medial-to-lateral entry angle.
  - As the spine ages, bony overgrowth usually occurs off the superior articular process. If the lateral border of the silhouette is targeted, it corresponds with the superior articular process, thereby resulting in a decreased probability of access (Fig. 15A.2C, D).

Tilt the fluoroscope cephalad or caudad, if needed.

- Little tilt is needed to optimize the entry into the joint.
- At the L5 to S1 level, the iliac crest may be superimposed over the Z-joint. Cephalad tilt may be required to optimize the trajectory view.
- In a scoliotic spine, cephalad or caudal tilt may be required to better visualize the vertebral level and the respective Z-joint of interest.

Place the needle parallel to the fluoroscopic beam.



Trajectory View Safety Considerations

- Avoid the spinal nerve by staying over the joint. Do not stray cranially above the joint.

Fig. 15A.1. A, Fluoroscopic image of a trajectory view with the needle in position at the left L4-L5 Z-joint. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

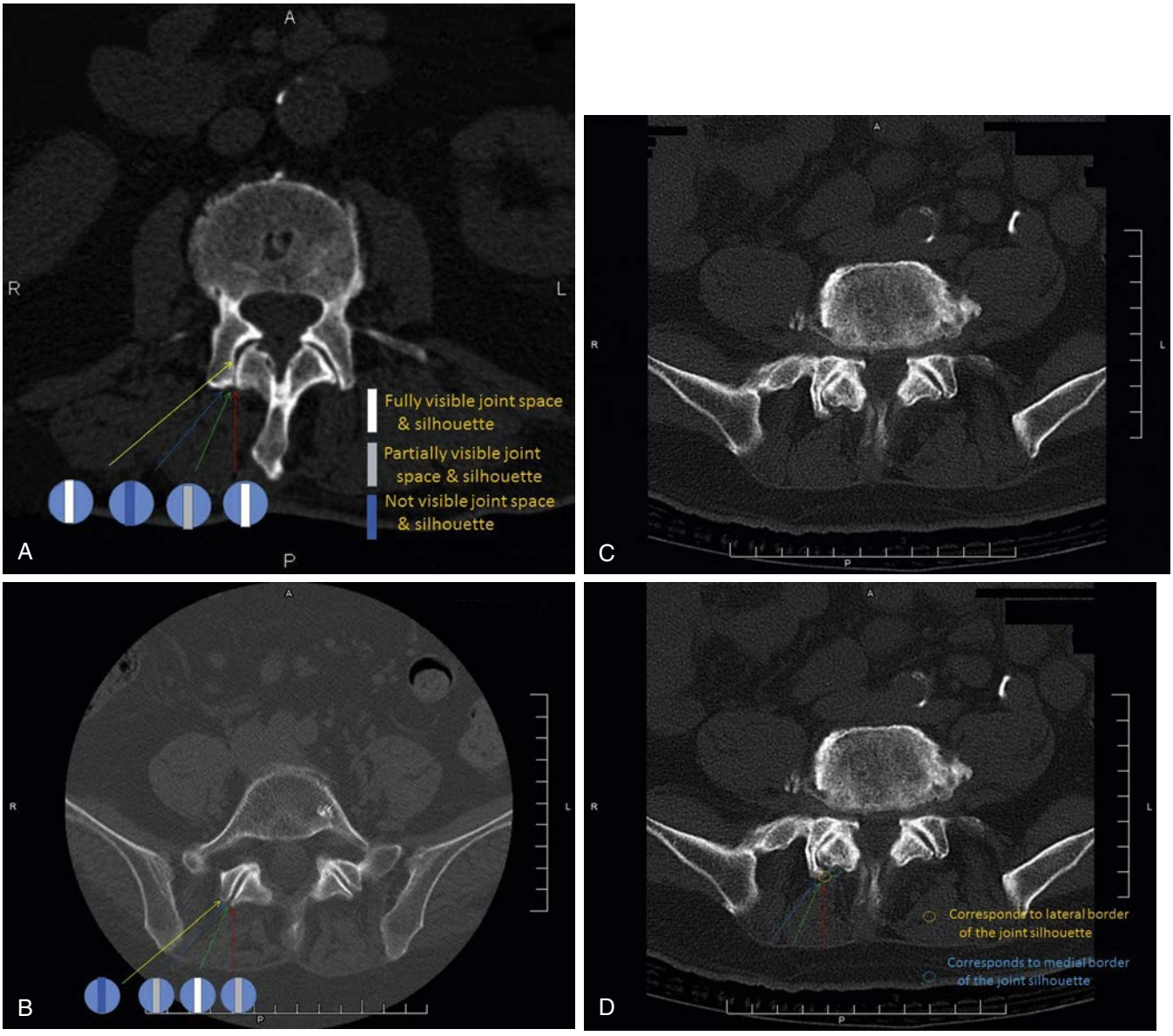


Fig. 15A.2. Axial lumbosacral computed tomography (CT) scans demonstrating the Z-joint orientation. **A,** In this sagitally oriented Z-joint, the joint silhouette and posterior (dorsal) access to the joint are best visualized at 0 degrees of ipsilateral obliquity *(red arrow)*. As one increases the ipsilateral obliquity, the joint silhouette is less well visualized and has less optimal posterior access to the joint *(green and blue arrows)*. Upon further obliquity *(yellow arrow),* the joint silhouette is again better visualized but now correlates with the ventral–medial aspect of the joint, which cannot be accessed posteriorly. **B,** In this more coronally oriented Z-joint, the joint silhouette and posterior (dorsal) access to the joint are best visualized not at 0 degrees *(red arrow)* but at approximately 20 degrees of ipsilateral obliquity *(green arrow)*. Upon further obliquity, the joint silhouette is less well visualized and has less optimal posterior access to the joint *(blue and yellow arrows)*. Also note that at the L5-S1 Z-joint, the iliac crest prevents a more oblique approach *(yellow arrow)*. **C,** Axial CT scan of a right L5-S1 Z-joint with degenerative changes, which are mainly noted on the superior articular process. **D,** Axial CT scan of a right L5-S1 Z-joint with degenerative changes demonstrating the lateral border of the joint silhouette corresponding to the superior articular process. If the needle is directed toward the lateral border, the needle trajectory would less likely enter the joint space. This joint may even need a slightly contralateral oblique trajectory angle.

Optimal Needle Position in Multiplanar Imaging

OPTIMAL NEEDLE POSITIONING IN THE OBLIQUE VIEW (FIG. 15A.3)

After the needle is placed in the trajectory view, oblique the C-arm more ipsilaterally until the joint space silhouette is clearly seen again. Advance the needle into the joint silhouette.

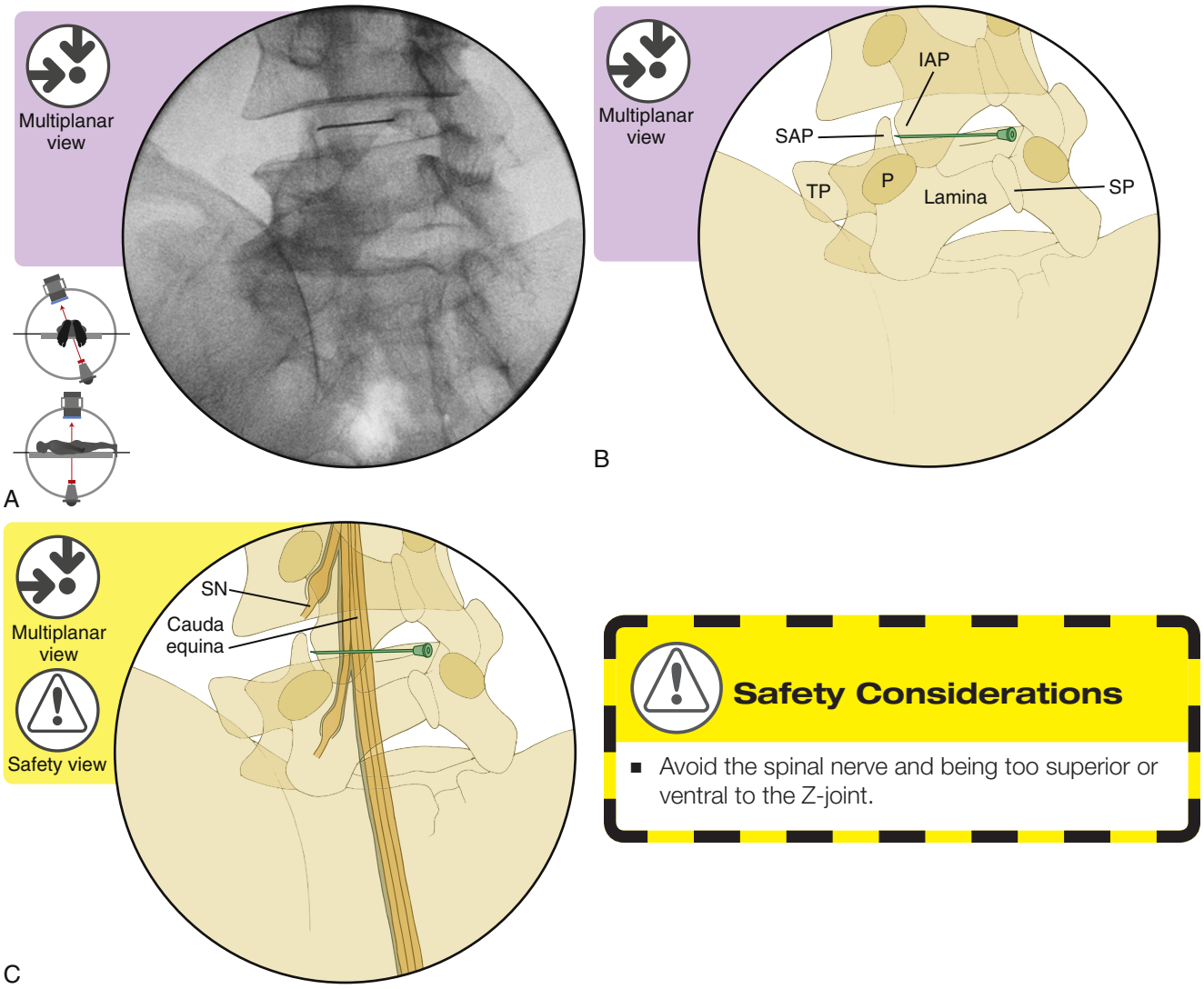


Fig. 15A.3. A, Oblique fluoroscopic view with ideal needle position within the joint. Note the medial-to-lateral needle orientation that results from using a less oblique trajectory. **B,** Radiopaque structures, oblique fluoroscopic view. **C,** Radiolucent structures, oblique fluoroscopic view.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 15A.4)

Notes on Optimal Needle Position

- The needle tip should be visualized within the joint silhouette with all imaging projections.

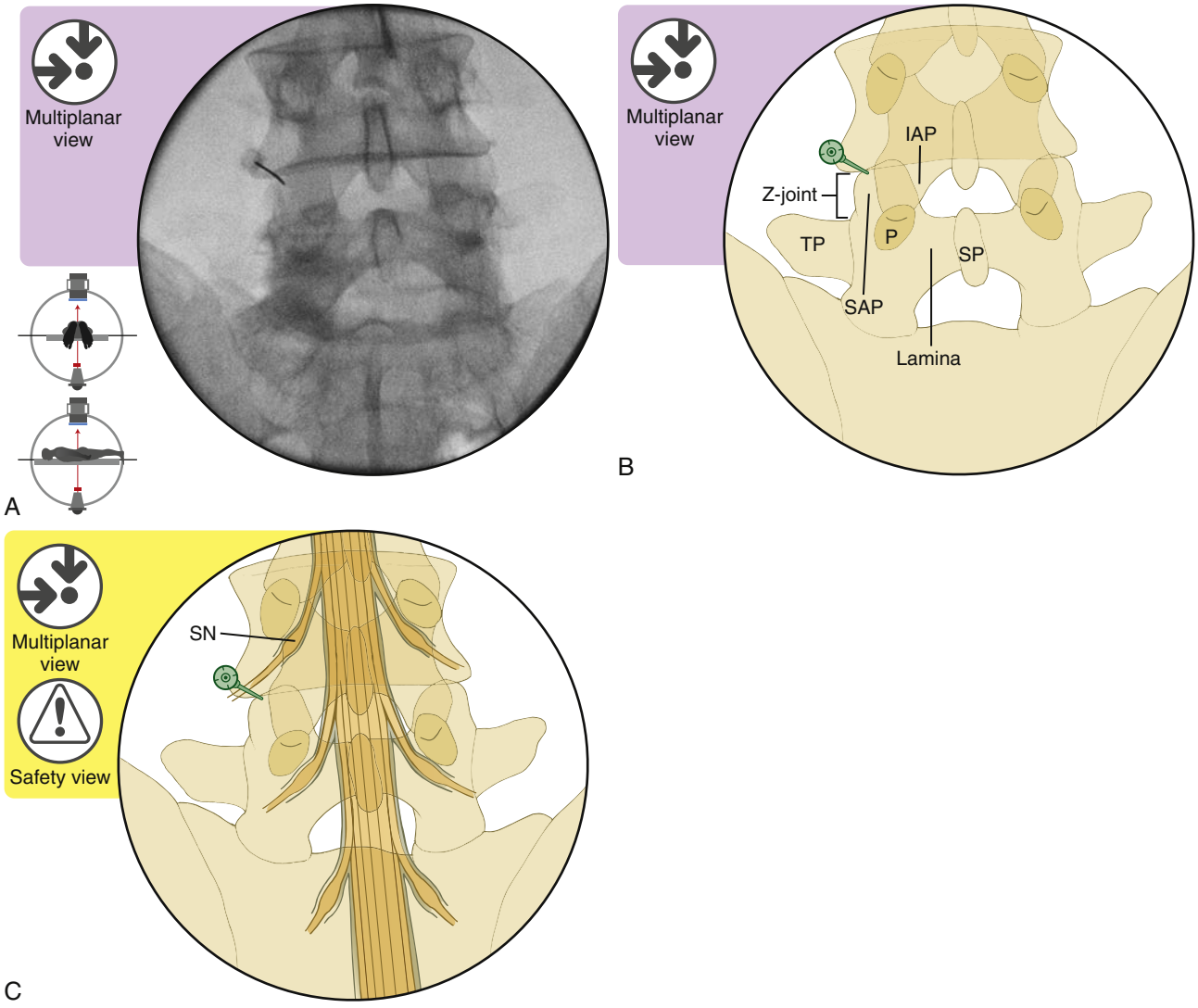


Fig. 15A.4. A, Anteroposterior fluoroscopic view with ideal needle position within the joint. **B,** Radiopaque structures, anteroposterior fluoroscopic view. **C,** Radiolucent structures, anteroposterior fluoroscopic view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 15A.5)

- A lateral view may be of additional value for estimating the needle depth and position.
- Needle depth may vary on the lateral view depending on the targeted region of the Z-joint.
  - When targeting the middle to upper half of the joint, the needle tip will be posterior to the joint silhouette.
  - When targeting the superior recess of the joint, the needle tip will be more ventral and closer to the level of the joint silhouette.

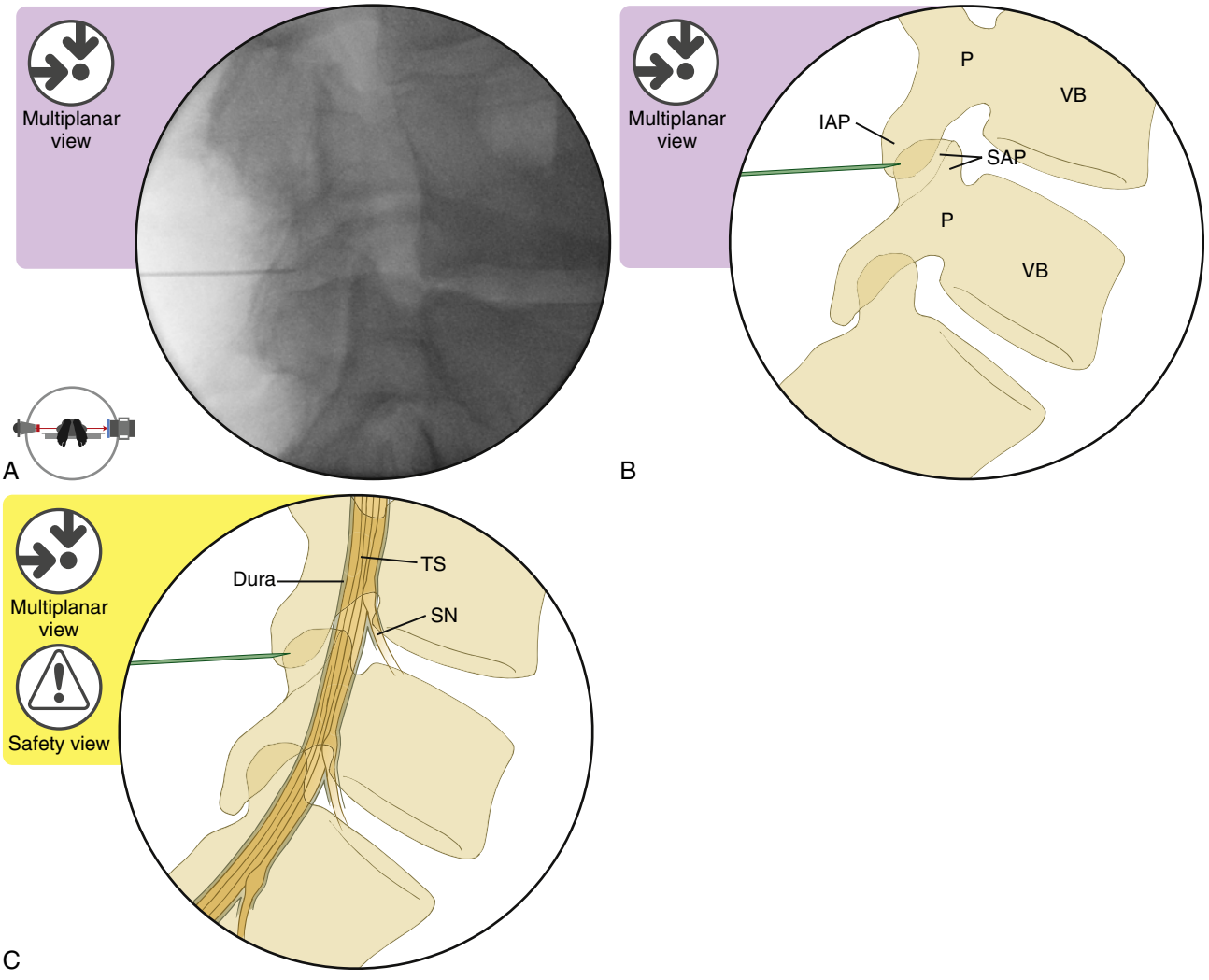


Fig. 15A.5. A, Lateral fluoroscopic view with ideal needle position within the joint. **B,** Radiopaque structures, lateral fluoroscopic view. **C,** Radiolucent structures, lateral fluoroscopic view.

Optimal Images (Fig. 15A.6)

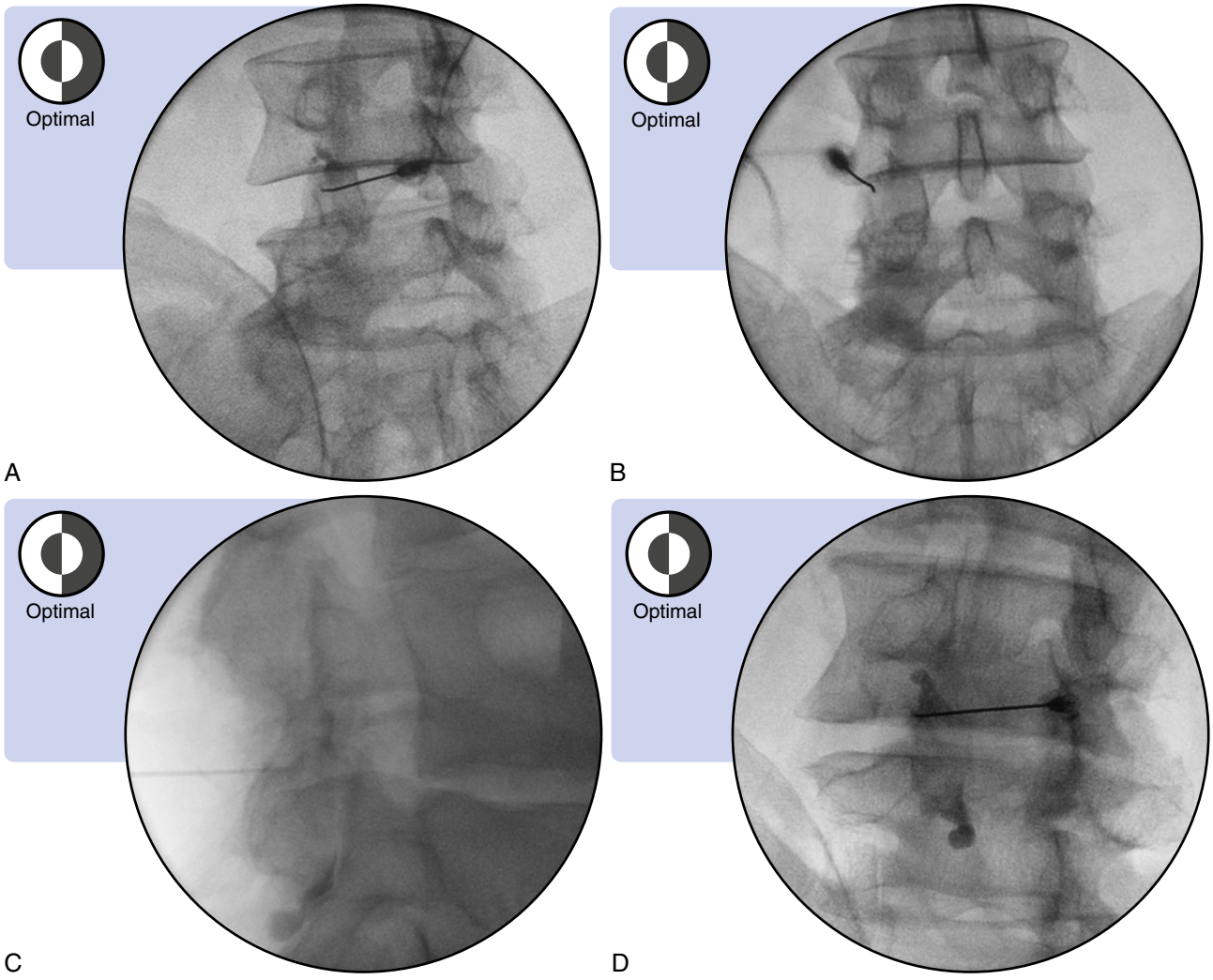


Fig. 15A.6. **A,** Oblique fluoroscopic image of a left L4-L5 Z-joint injection with 0.3 cc of contrast medium. **B,** Anteroposterior fluoroscopic image of the lumbar Z-joint injection with 0.3 cc of contrast medium. **C,** Lateral fluoroscopic image of the lumbar Z-joint injection with 0.3 cc of contrast medium. **D,** Oblique fluoroscopic image of a left L4-L5 Z-joint injection outlining the superior and inferior recesses.

Additional Optimal Images (Figs. 15A.7 and 15A.8)

Optimal Image

- Ideal flow should fill the joint silhouette or outline the inferior articular process, or should do both. At times, one may see filling of the superior or inferior recess.
- For cases of severe Z-joint arthropathy, the needle and subsequent flow may need to be targeted toward the inferior or superior recess.
- The maximum volume of injectate for each joint is 1.0 to 1.5 cc. One should limit the volume of contrast so that enough therapeutic injectate can be delivered into the joint space.

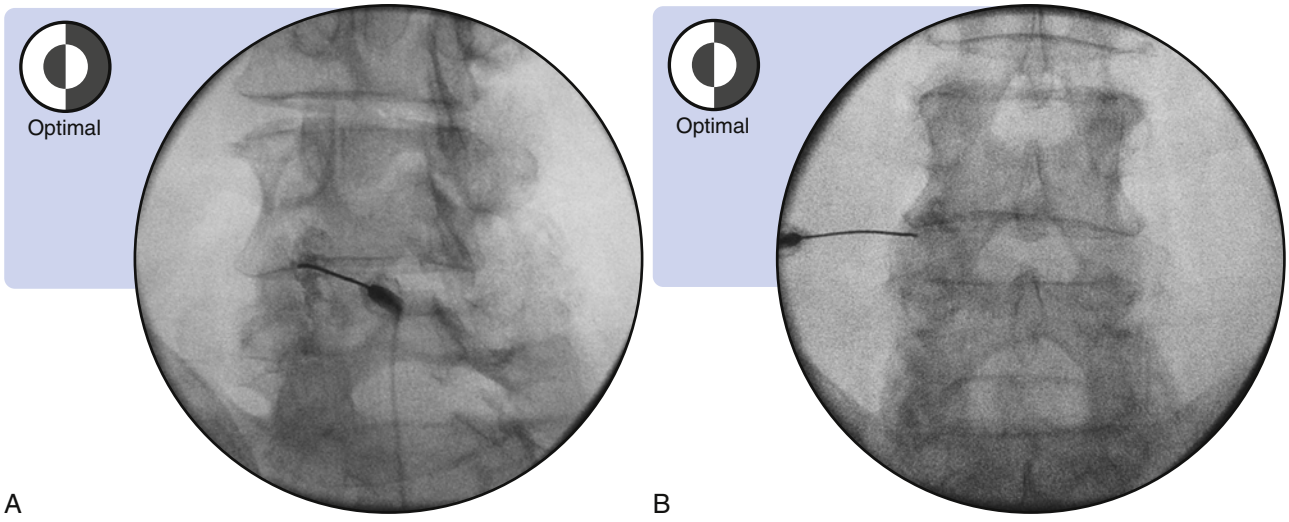


Fig. 15A.7. A, Oblique fluoroscopic image of a left L4-L5 Z-joint injection with 0.3 cc of contrast medium within the joint silhouette. **B,** Anteroposterior fluoroscopic image of the left L4-L5 Z-joint injection with 0.3 cc of contrast medium.

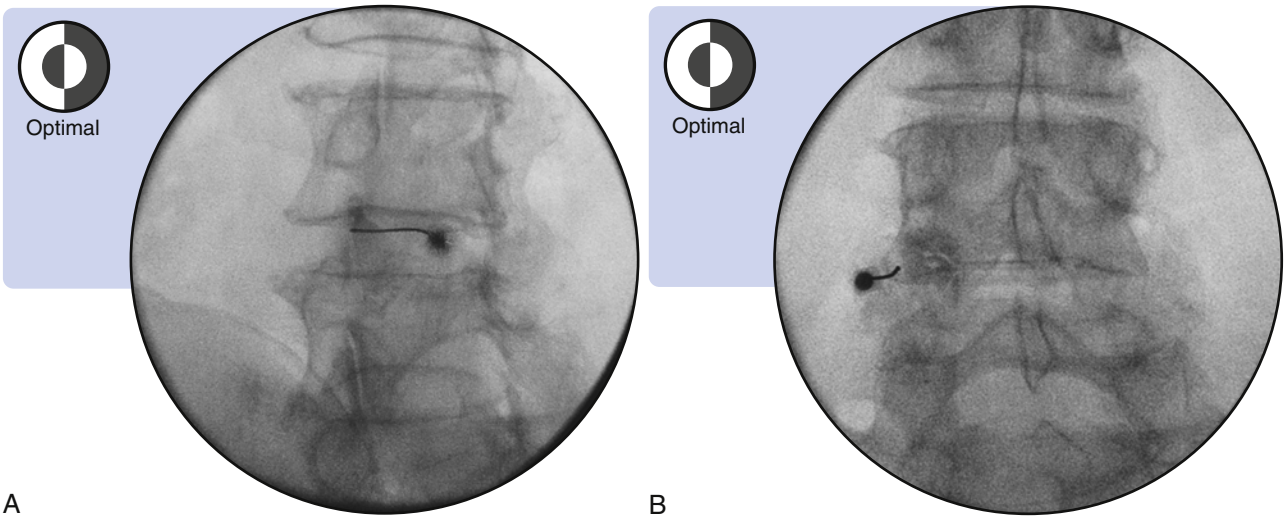


Fig. 15A.8. A, Oblique fluoroscopic image of a left L4-L5 Z-joint injection with 0.4 cc of contrast medium outlining the inferior articular process. **B,** Anteroposterior fluoroscopic image of the left L4-L5 Z-joint injection with 0.4 cc of contrast medium.

Suboptimal Image (Figs. 15A.9 and 15A.10)

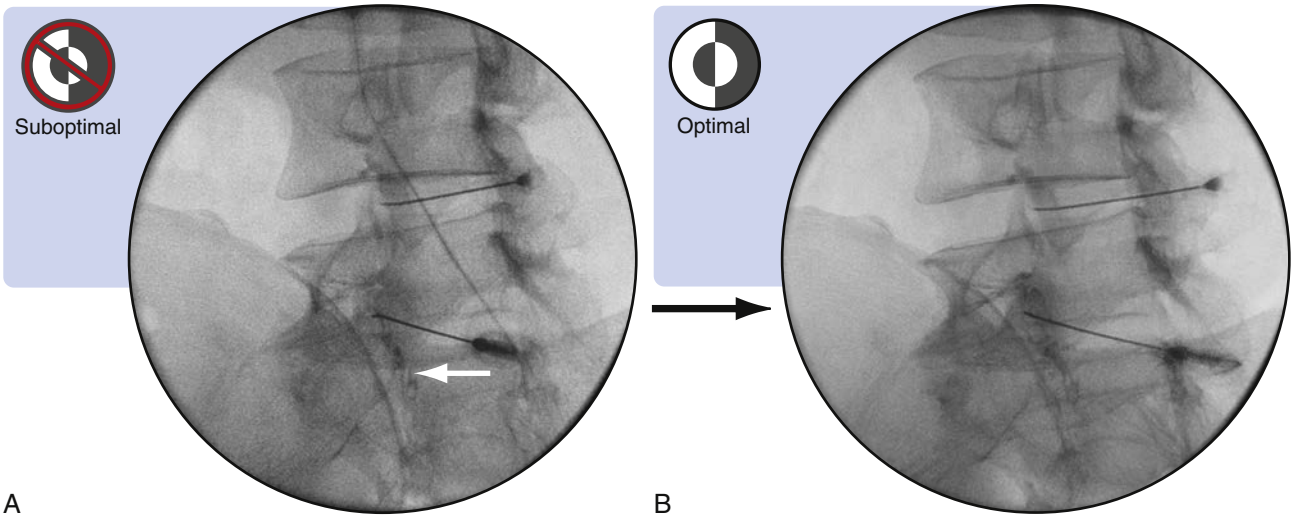


Fig. 15A.9. A, Oblique view of a left L5-S1 Z-joint injection with mainly soft-tissue uptake (white arrow). There needs to be a clearer demonstration of contrast within the joint silhouette. **B,** After repositioning the needle, this oblique fluoroscopic image now demonstrates optimal flow.

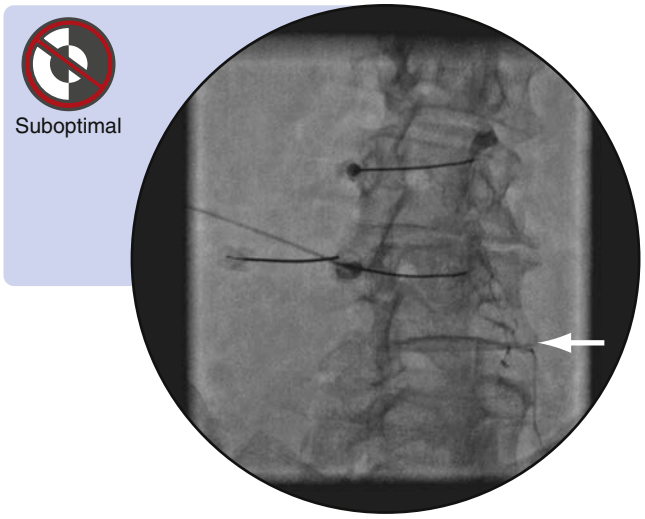


Fig. 15A.10. Fluoroscopic image demonstrating vascular flow with a right L3-L4 Z-joint injection (arrow). Although the image is static, when it is observed under live fluoroscopy, the contrast rapidly dissipates.

Additional Views (Figs. 15A.11 and 15A.12)

Depending on the patient's anatomy, one may need to target the superior or inferior recess. There may be times when arthritic changes in the Z-joint may be severe. Bone spurring typically occurs at the superior articular process, and it may prohibit access into the joint through the typical target location. When using the superior recess approach, multiplanar views are essential (i.e., anteroposterior, oblique, and lateral views).

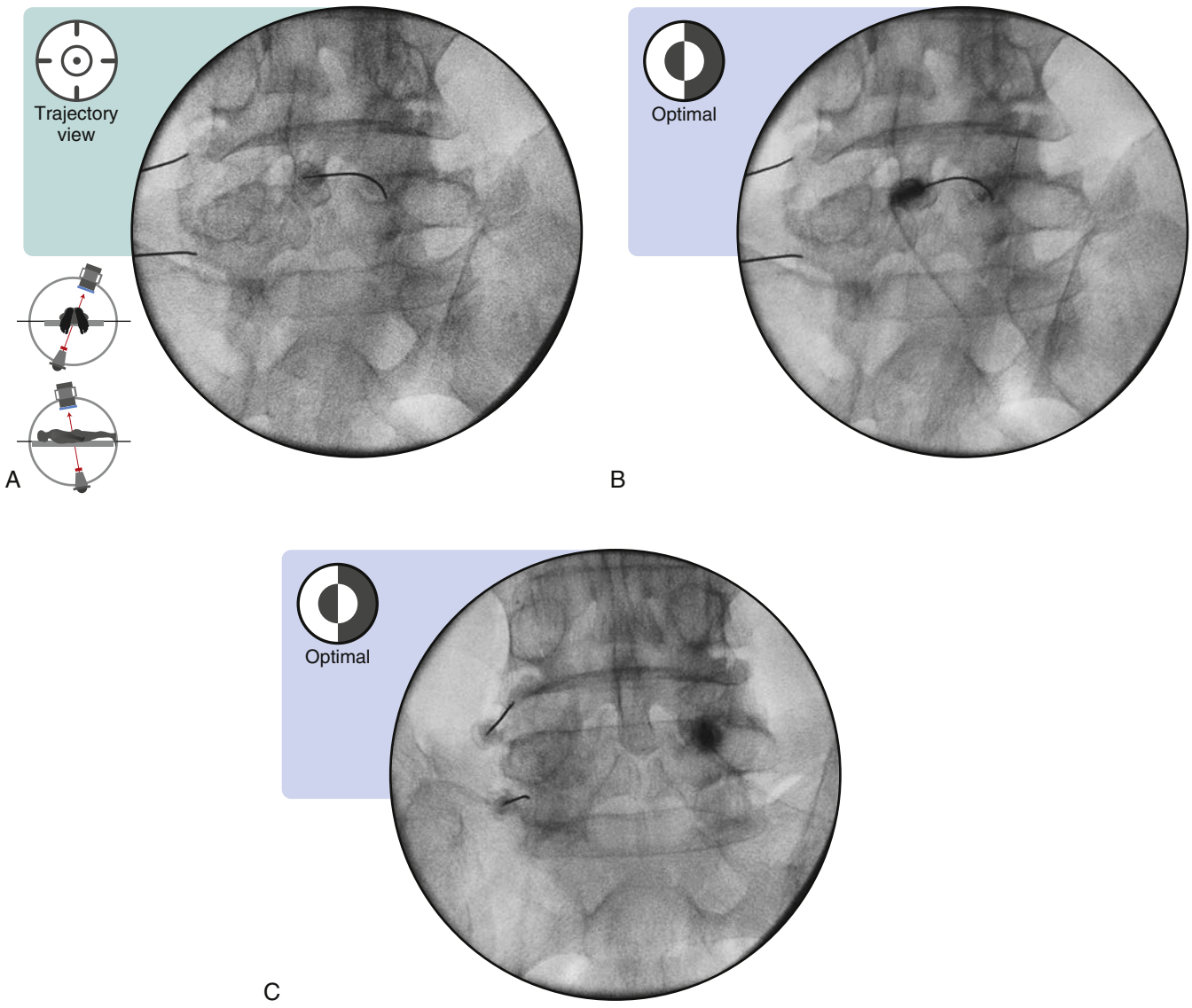


Fig. 15A.11. A, Oblique (trajectory) view of a right L4-L5 Z-joint injection with needle access via the inferior recess without contrast. The hub has been moved away to demonstrate the position of the needle tip. **B,** Oblique view of the L4-L5 Z-joint injection with contrast. **C,** Anteroposterior view of the L4-L5 Z-joint injection with contrast.

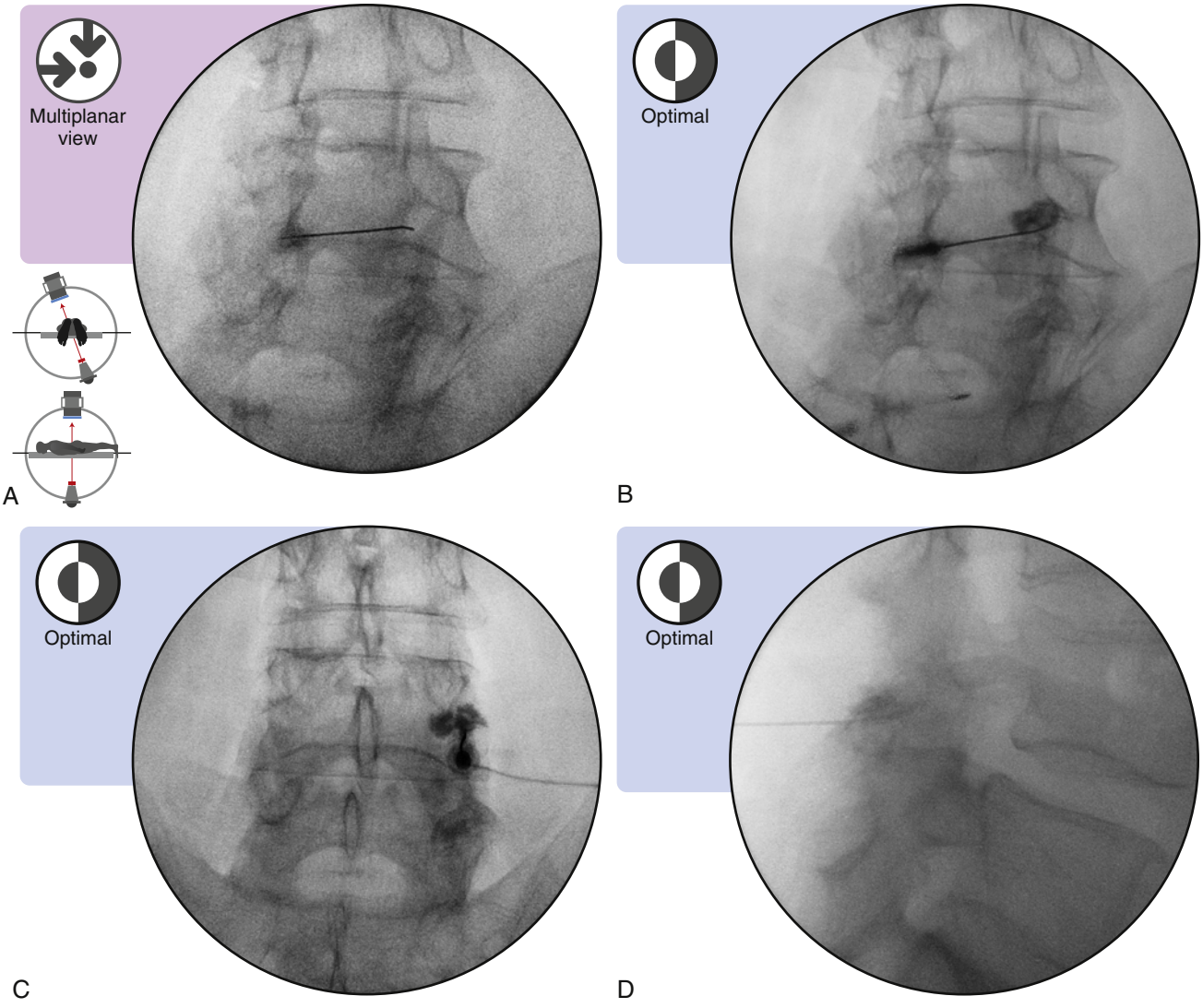


Fig. 15A.12. A, Oblique view of a right L4-L5 Z-joint injection with needle access via the superior recess without contrast. **B,** Oblique view of the L4-L5 Z-joint injection with contrast. **C,** Anteroposterior view of the L4-L5 injection with contrast. **D,** Lateral view of the L4-L5 Z-joint injection with contrast.

Alternative Technique for the Caudad Lumbar Zygapophysial Joints (Fig. 15A.13)

Anatomically, the caudad Z-joints are coronally oriented and shaped like the letter "C" or "J." With the coronal orientation of the joints, the posterior joint space is generally more laterally positioned than the upper joint space, which tends to be sagittally oriented from the midline. As a result, one can access the Z-joint using the anteroposterior view and place the needle medial to the lateral border of the Z-joint outline. This approach would be in lieu of the traditional oblique technique. Then, one would rotate ipsilateral and oblique to find the silhouette and to advance the needle into the joint.

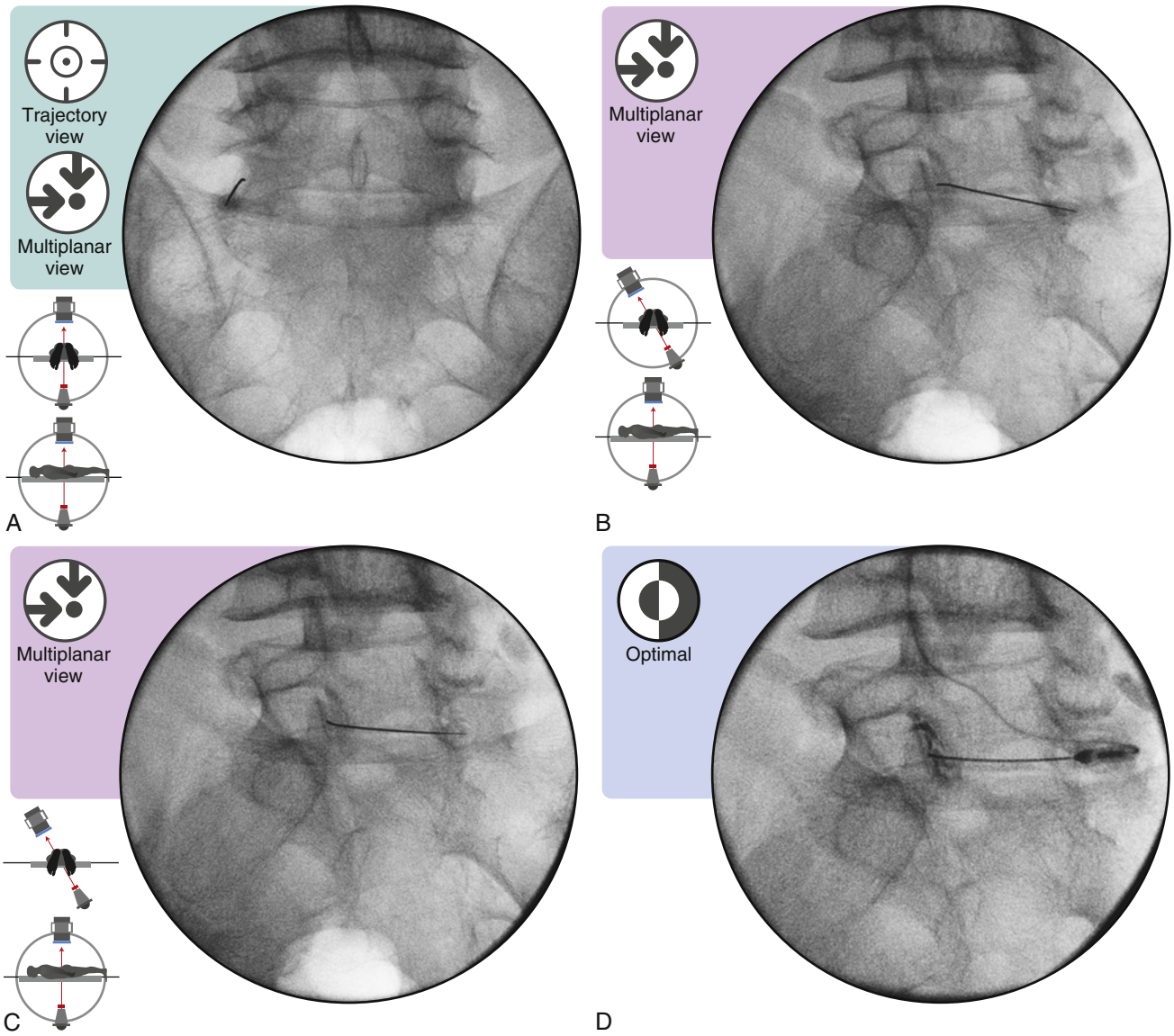


Fig. 15A.13p1. A, Anteroposterior view of a left L5-S1 Z-joint injection without contrast. **B,** Initial oblique view of the same left L5-S1 Z-joint injection without contrast. **C,** Oblique view of the same left L5-S1 Z-joint injection after advancement into the Intraarticular space. **D,** Oblique view of the same left L5-S1 Z-joint injection with contrast.

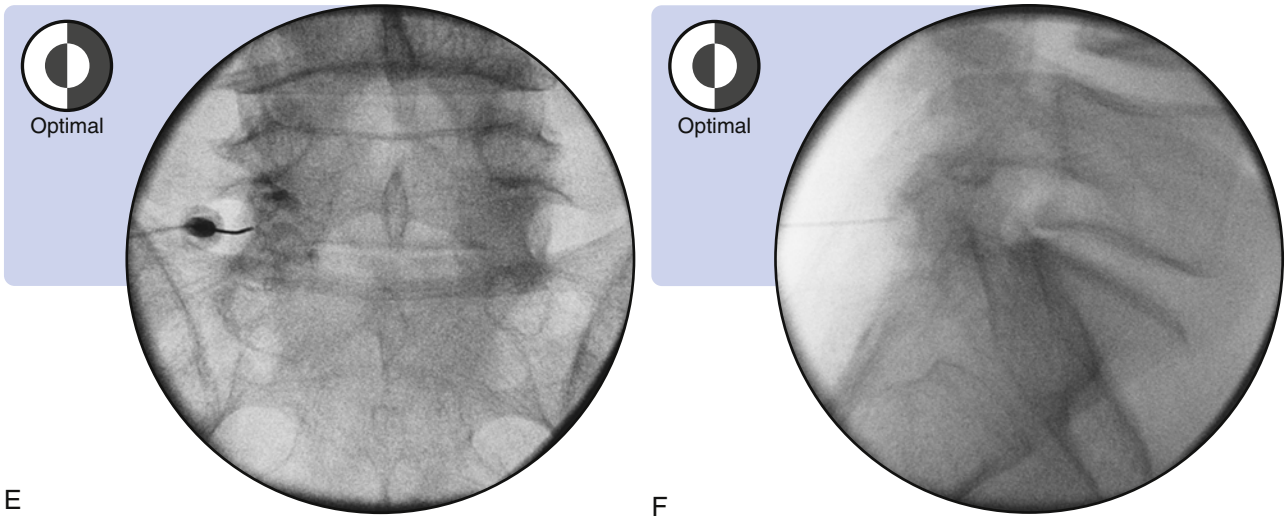


Fig. 15A.13p2. E, Anteroposterior view of the same left L5-S1 Z-joint injection with contrast. **F,** Lateral view of the same left L5-S1 Z-joint injection with contrast.

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CHAPTER 15B

Lumbar Zygapophysial Joint Nerve (Medial Branch) Injection—Oblique Approach: Fluoroscopic Guidance

Leland Berkwits, Jason G. Anderson, Luis Baez-Cabrera, and Michael B. Furman

The fluoroscopically guided lumbar medial branch block will be described using the oblique view as the trajectory view, and needle placement is confirmed in the anteroposterior view. The oblique approach is the most convenient and the least technically demanding, and it allows one to accurately and consistently reach the target point.

This oblique (trajectory) view is one of the multiplanar views used to guide needle placement. With well-defined target points and needle trajectories required to provide specific anesthetization of the zygapophysial joint, the volume of local anesthetic injected should be limited to 0.4 to 0.5 ml to maintain the diagnostic specificity of the injection.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

- **Confirm the level** (with the anteroposterior view).
- **Tilt the fluoroscope's image intensifier** to line up the vertebral superior end plate of the targeted segment.
- Oblique the C-arm image intensifier ipsilaterally to form the "Scotty dog" and optimize visualization of the junction of the transverse process and superior articular process.
- For the L1 to L4 medial branches, the target needle destination is the junction of the superior articular process and transverse process, where the target nerve crosses midway between the superior border of the transverse process and mamillo-accessory ligament (MAL) notch. This is often described as just superior to the "eye of the Scotty dog."
- For the L5 dorsal ramus, the target nerve is not the medial branch but rather the L5 dorsal ramus. This nerve courses over the ala of the sacrum on a path similar to the L1 to L4 medial branches. However, the MAL at the S1 bony segment is rudimentary.
- The L5 dorsal ramus target point is located at the middle of the base of the superior articular process, and therefore, slightly below the sacral ala. If the iliac crest interferes with the placement of the needle at the L5 dorsal ramus, oblique the fluoroscope 5 to 10 degrees back toward anteroposterior to visualize a non-obstructed trajectory to the junction of the superior articular process and sacral ala.
- Both of the nerves that innervate each targeted lumbar zygapophysial joint will need to be anesthetized.
- The needle should be placed parallel to the fluoroscopic beam in this trajectory view.
- The zygapophysial joint capsule is adjacent to the medial border of the superior articular process. As a result of joint capsule redundancy, it is possible to have intraarticular flow if the needle is medial to the optimal target point. Intraarticular flow can complicate the diagnostic specificity of the injection and more so if there is epidural leakage from the medial capsule.

Trajectory View (Ipsilateral Oblique) Is Also a Multiplanar View (Fig. 15B.1)

Notes on Positioning in the Trajectory View

- **L1 to L4 medial branches:** An appropriate needle trajectory requires the adjustment of fluoroscopic tilt at each level.
  - This is particularly an issue at the L5 vertebral body (i.e., the L4 medial branch nerve) because of the lordosis at this level. In addition, patients with scoliosis may pose particular challenges with regard to obtaining an appropriate needle trajectory because the vertebrae are no longer oriented in the same sagittal plane.
  - Place the needle more superiorly along the base of the superior articular process (SAP) to avoid the MAL (see Fig. 15B.1C).
- **L5 dorsal ramus:** The iliac crest may block the needle trajectory. Therefore, a less oblique approach of 5 to 10 degrees is taken for the L5 dorsal ramus. Note that the MAL at this segment is rudimentary, and, thus, permits a more sagittal approach.
- While a single oblique trajectory may be possible for multiple targeted medial branch nerves, anatomic variations may require an individualized, nonparallel, trajectory view for each individual targeted nerve.

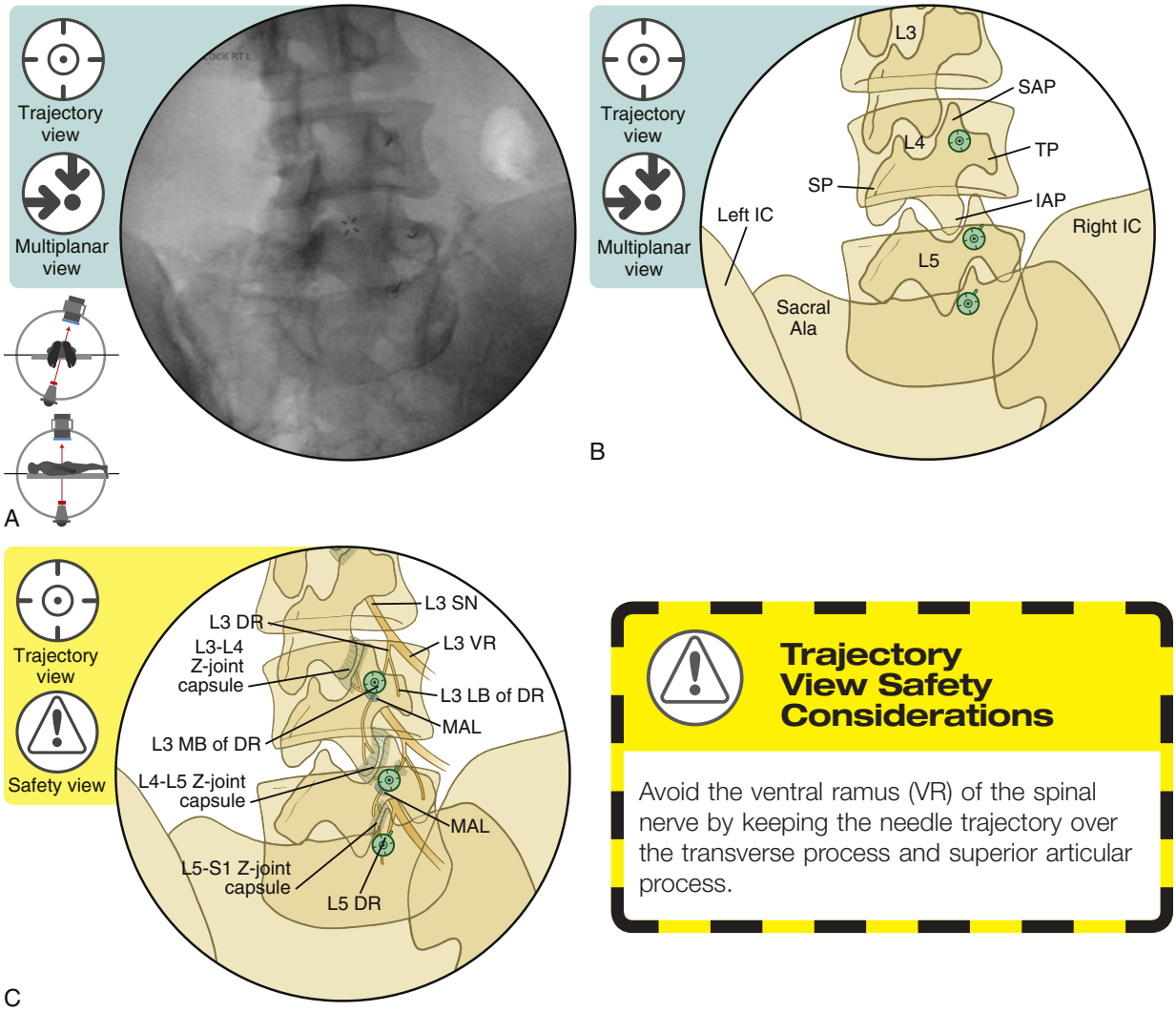


Fig. 15B.1. A, Fluoroscopic image of a trajectory view for vertebral bodies L3 to L5 with the needle in the optimal position. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view. While a single oblique trajectory may be possible for multiple targeted medial branch nerves, anatomic variations may require an individualized, nonparallel, trajectory view for each individual targeted nerve.

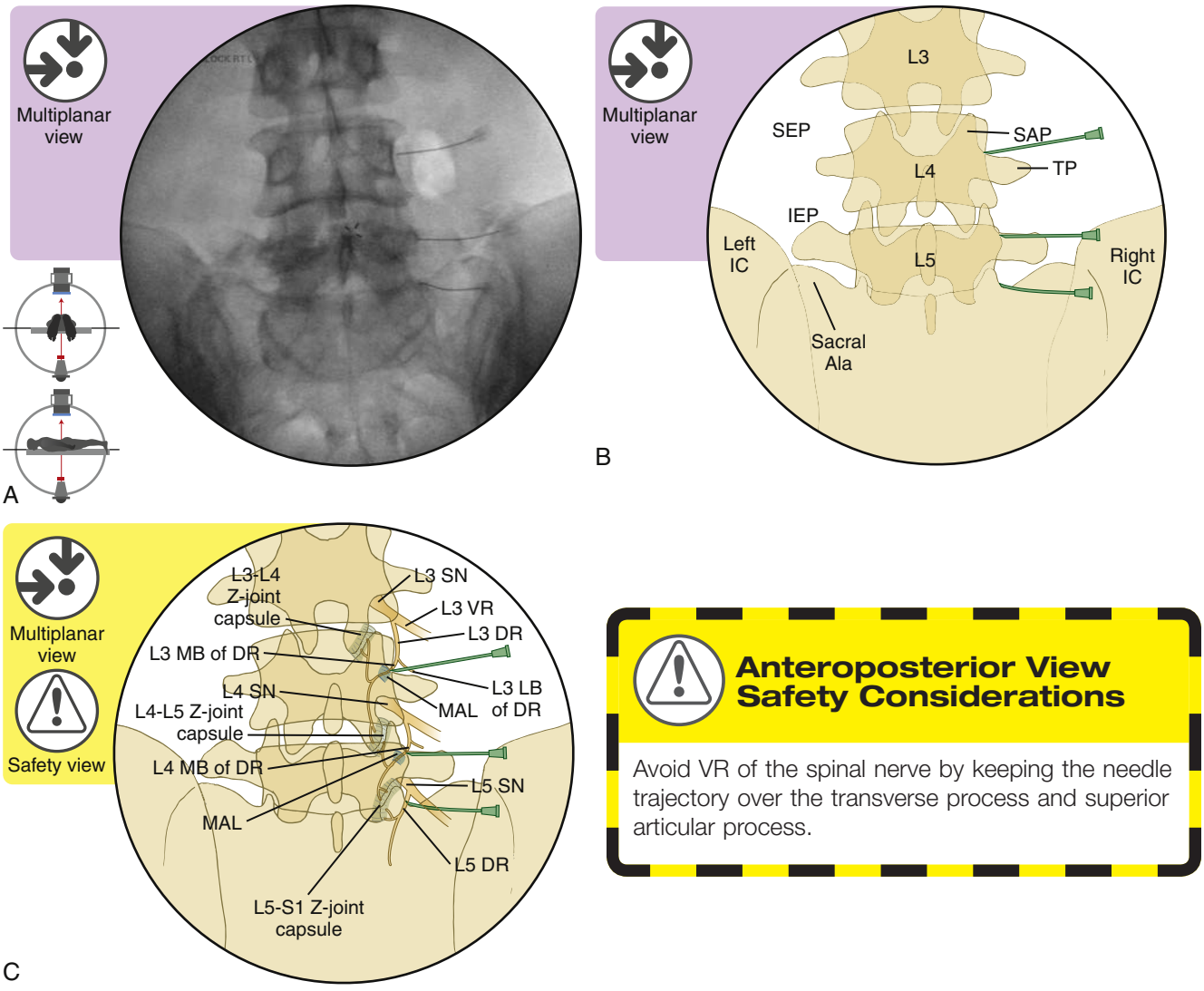
Optimal Needle Position in Multiplanar Imaging

The recommended multiplanar views are ipsilateral oblique (trajectory), anteroposterior, and lateral.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 15B.2)

Notes on Positioning in the Multiplanar Views

Please see Figs. 15E.1 and 15E.2 for diagrams and figures depicting position of the medial branches and dorsal rami in multiple views.

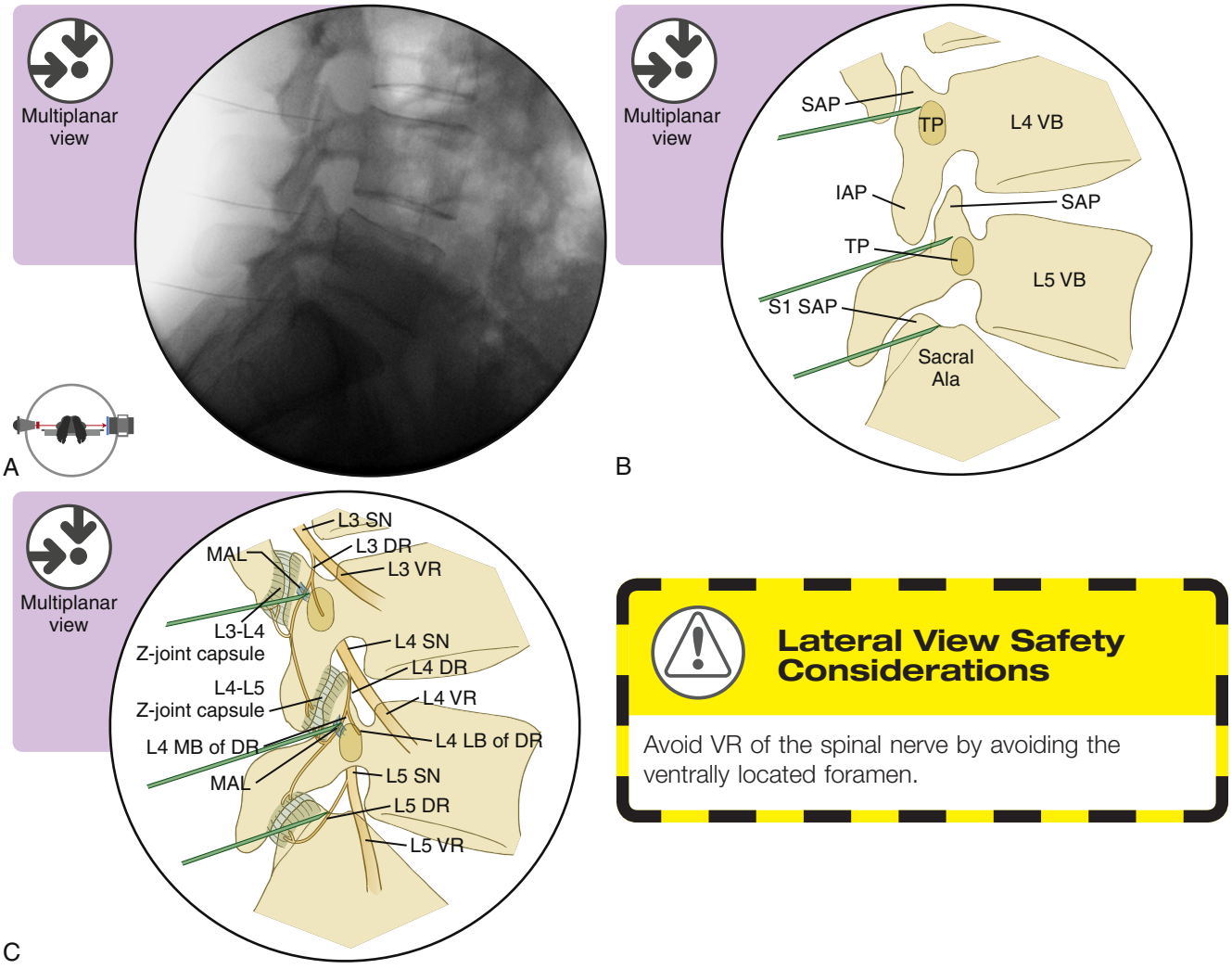


Anteroposterior View Safety Considerations

Avoid VR of the spinal nerve by keeping the needle trajectory over the transverse process and superior articular process.

Fig. 15B.2. A, Fluoroscopic anteroposterior view with the ideal needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 15B.3)



Lateral View Safety Considerations

Avoid VR of the spinal nerve by avoiding the ventrally located foramen.

Fig. 15B.3. A, Fluoroscopic lateral view with the ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images (Fig. 15B.4)

A caudally positioned bevel may reduce the likelihood of an epidural spread.

L1 to L4 medial branches: Contrast flow will smoothly outline the medial border, thereby indicating the spread of contrast along the lateral surface of the base of the superior articular process, without epidural or vascular flow.

L5 dorsal ramus: Contrast flow will form a smooth margin around the base of the superior articular process of the sacrum, without epidural or vascular flow.

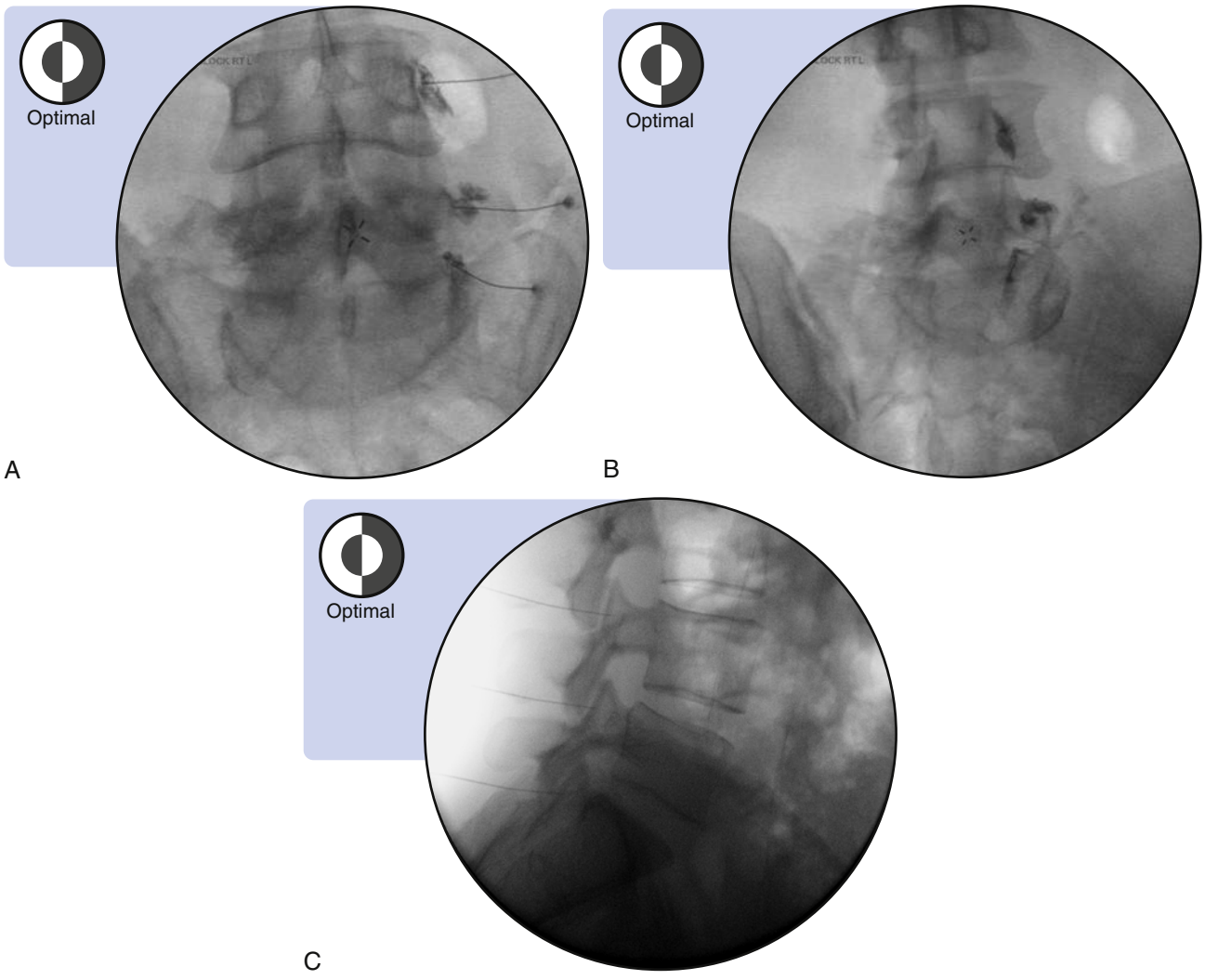


Fig. 15B.4. A, Anteroposterior fluoroscopic image of L3 medial branch, L4 medial branch, and L5 dorsal ramus injections with 0.5 cc of contrast medium per level. **B,** Oblique fluoroscopic image. **C,** Lateral fluoroscopic image.

Suboptimal Images (Figs. 15B.5 and 15B.6)

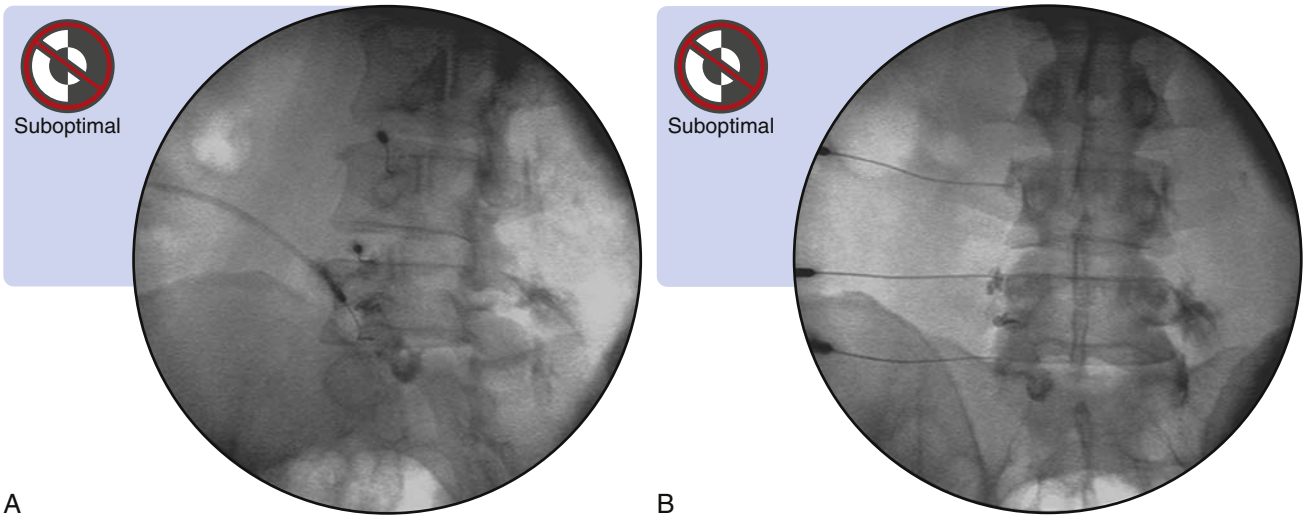


Fig. 15B.5. Intraarticular contrast flow is noted into the L5 to S1 Z-joint on the left, with the injection of contrast medium at the L5 dorsal ramus. **A,** Trajectory view. **B,** Anteroposterior view.

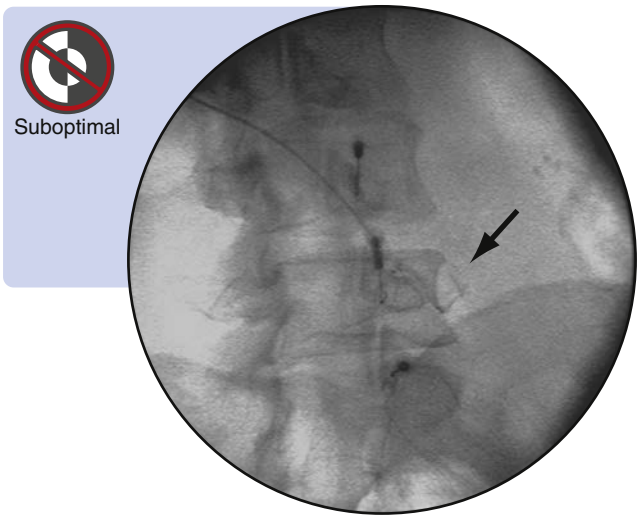


Fig. 15B.6. Fluoroscopic image demonstrating the vascular flow of the injection of contrast medium at the L4 medial branch (arrow). Although the image is static, when observed under live fluoroscopy, the contrast rapidly dissipates.

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CHAPTER 15C

Lumbar Zygapophysial Joint Nerve (Medial Branch) Radiofrequency Neurotomy—Posterior Approach: Fluoroscopic Guidance

Ruby E. Kim, Luis Baez-Cabrera, James J. Gilhool, and Michael B. Furman

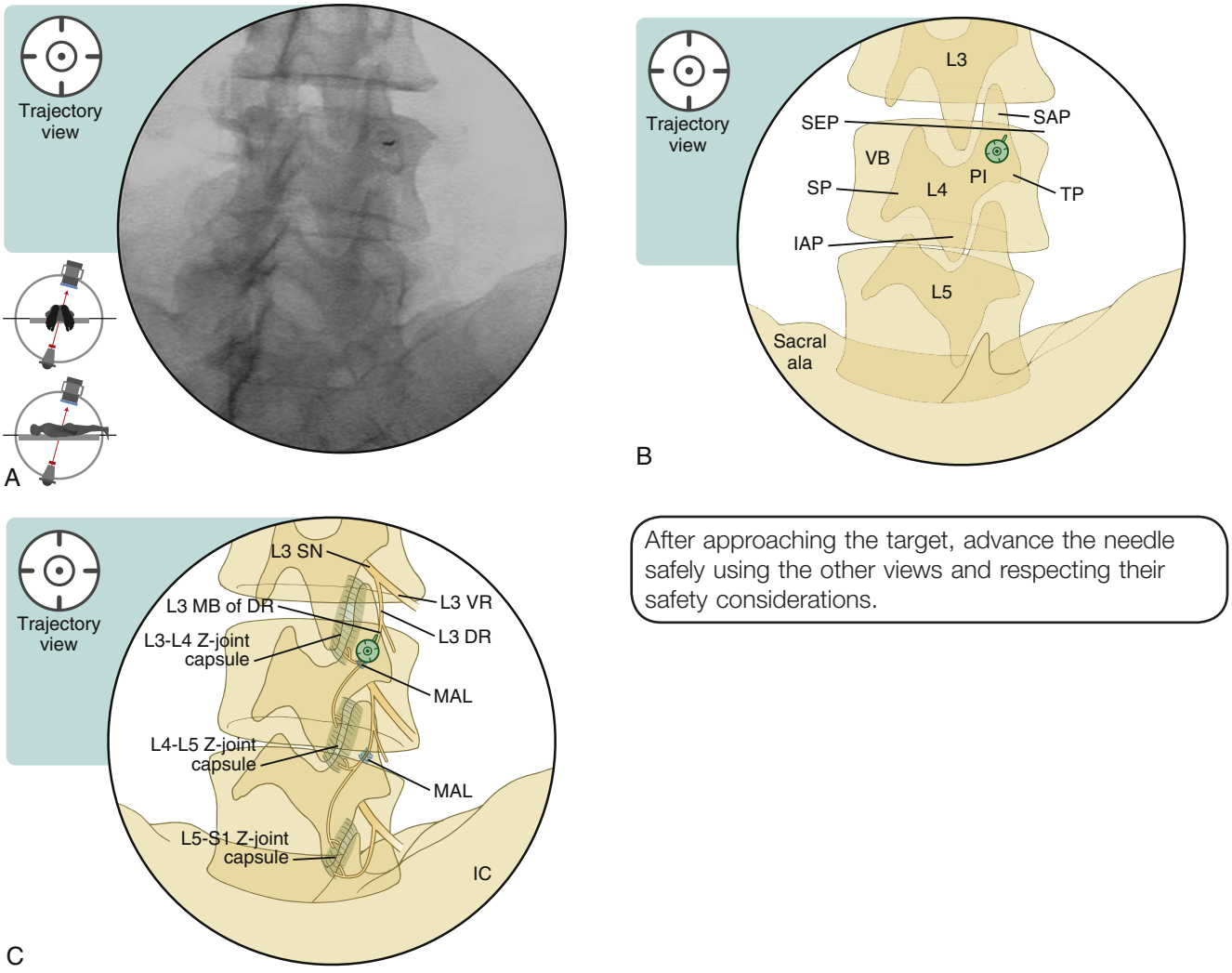
Often-used synonyms for "neurotomy" include "ablation," "denervation," and "lesion." We do not recommend the term "rhizotomy" because it implies lesioning of nerve roots.

The lumbar radiofrequency neurotomy approach is described as needle placement using a trajectory view and advancement using multiplanar imaging, with an emphasis on safety using the lateral and ipsilateral oblique views to confirm the depth and readiofrequency electrode tip placement parallel to the targeted nerve. Before neurotomy, sensory, and motor stimulation confirm nonradicular stimulation and prior to neurotomy, 0.5 to 1 cc volume of local anesthetic is typically administered for patient comfort. The time and duration of the denervation vary between practitioners (e.g., up to three 90-second cycles at 80°C–85°C).

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

- **Confirm the level** with the targeted medial branch nerve (with the anteroposterior [AP] view).
- **Oblique and tilt the C-arm image intensifier to obtain an optimal AP view** with the spinous process (SP) at midline and squaring off the superior end plate (SEP) of the vertebral body.
- **Oblique the C-arm image intensifier** about 20 degrees toward the symptomatic side (the right side, in this case) (do NOT oblique for the L5 dorsal ramus as noted below).
- **Tilt the C-arm image intensifier about 40 to 45 degrees caudally** from the squared SEP.
  - Note that this is one of the few procedures where we recommend specific angles.
- **An alternate method to estimate the tilt angle is to mark the immediately inferior target and tilt that point as demonstrated in Videos 15C.1 and 15C.2.**
- This angle is used for entry and to approximate the trajectory of the target nerve for a "parallel placement" along the nerve.
- The electrode tip destination is the lateral border of the superior articular process (SAP) and the very small concavity that is formed by the junction of SAP and the transverse process.
- At the L5 level, there is only a rudimentary mamillo-accessory ligament (MAL), and the iliac crest will interfere with oblique needle positioning. Therefore, the oblique trajectory angle will be close to 0 degrees.
- As this is the trajectory view, the needle entry position should be parallel to the C-arm beam (Fig. 15C.1).



After approaching the target, advance the needle safely using the other views and respecting their safety considerations.

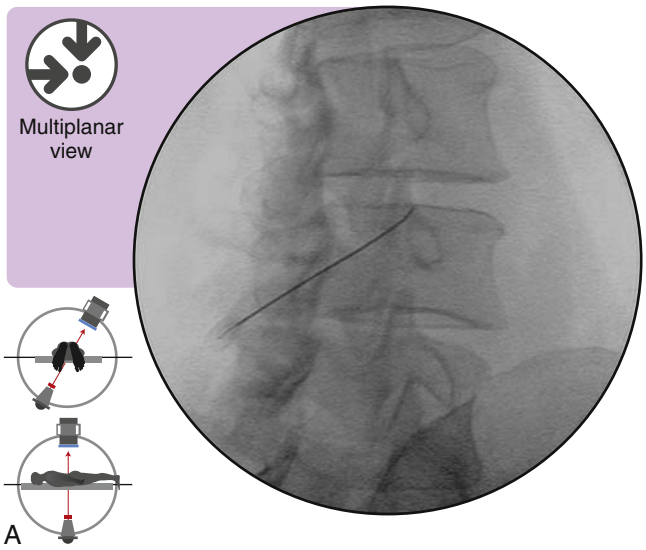
Fig. 15C.1. A, Fluoroscopic image of a trajectory view with the radiofrequency electrode tip in position over the right L3 medial branch nerve. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view. Please see above for setup details. The electrode is placed so that it lies parallel to the trajectory of the target nerve.

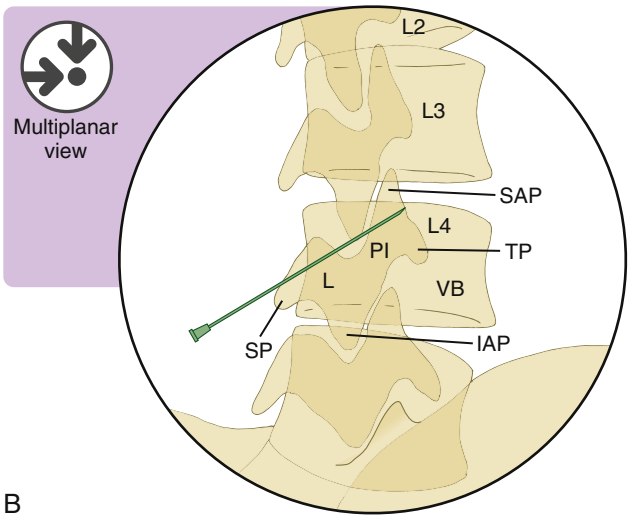
Optimal Needle Position in Multiplanar Imaging

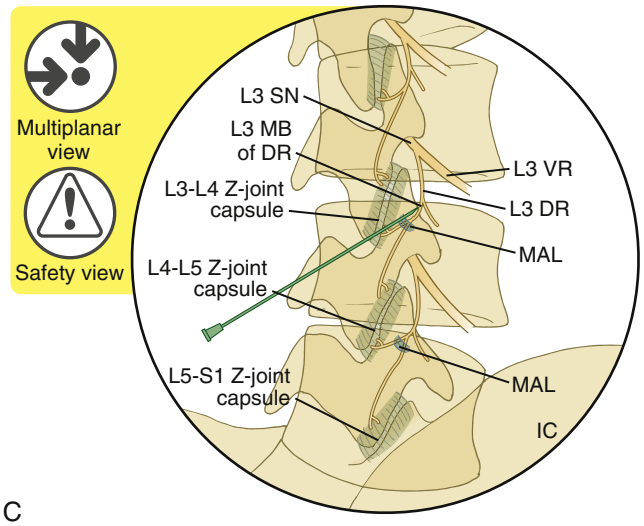
For radiofrequency denervation, after the needle tip has reached its target via the trajectory view, three other views—ipsilateral oblique, anteroposterior, and lateral—are obtained for the final confirmation of the electrode tip position before neurotomy.

OPTIMAL NEEDLE POSITIONING IN THE IPSILATERAL OBLIQUE VIEW (FIG. 15C.2)

When the needle is placed in the trajectory view, oblique the C-arm image intensifier further toward the symptomatic side to confirm that the needle tip is placed at the lateral border of SAP and the concavity that is formed by the junction of SAP and the transverse process. Stay along the base of SAP to remain superior to MAL (Fig. 15C.2C) for the L1 to L4 medial branches. Note that MAL at the L5 segment is rudimentary and, thus, permits a more sagittal approach for the L5 dorsal ramus. This oblique view is different from the trajectory view because the length of the needle is visualized in the oblique view to confirm the proper position of the needle tip.







Ipsilateral Oblique Safety View Considerations

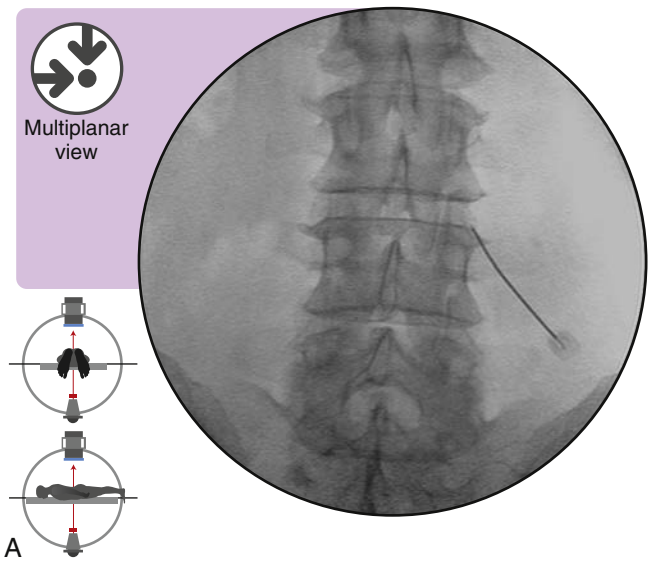
Avoid SN, VR, and DR:

- Confirm that the electrode does not advance beyond the superolateral edge of the SAP.
- Reposition the radiofrequency electrode if the patient complains of paresthesias or pain radiating to the lower limb during the electrode placement, stimulation, or neurotomy.

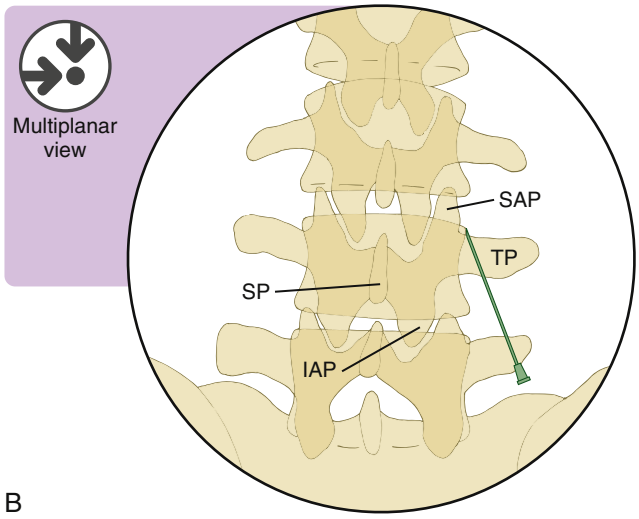
Fig. 15C.2. A, Fluoroscopic image of an ipsilateral oblique view with the radiofrequency electrode in position over the right L3 medial branch nerve. **B,** Radiopaque structures, oblique view. **C,** Radiolucent structures, oblique view. Please see Figs. 15E.1 and 15E.2 for additional details about Z-joint anatomy/innervation and ideal radiofrequency electrode placement.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 15C.3)

Return to the AP view to confirm that the needle tip is placed at the lateral border of SAP and the concavity that is formed by the junction of SAP and the transverse process. Stay along the base of SAP to remain superior to MAL (Fig. 15C.3C) for the L1 to L4 medial branches. Note that MAL at the L5 segment is rudimentary and, thus, permits a more sagittal approach for the L5 dorsal ramus.



A



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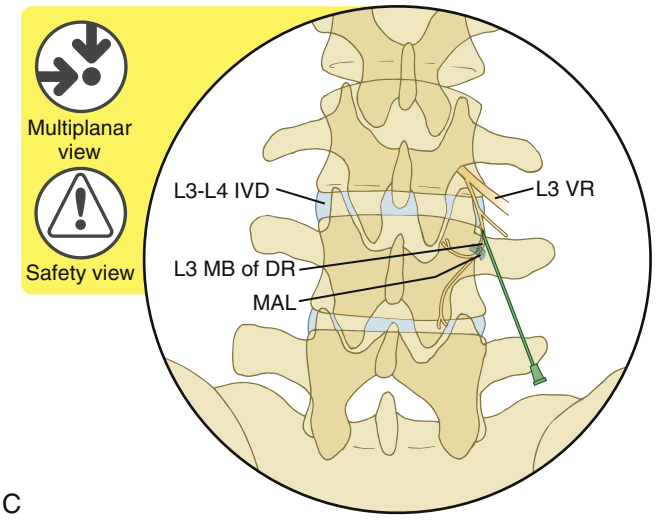


C

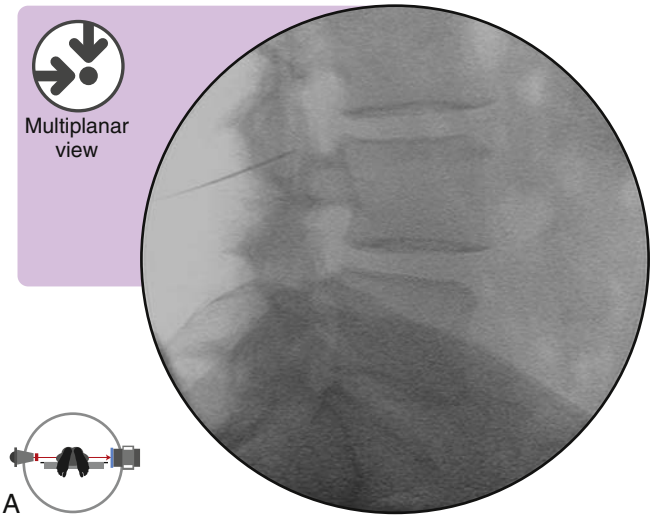
Anteroposterior View Safety Considerations

- Confirm that the radiofrequency electrode is not too medial (i.e., not located in the intervertebral foramen [IVF] where the ventral ramus lies or in the intervertebral disc space or spinal canal).
- Reposition the radiofrequency electrode if the patient complains of paresthesias or pain in the lower limb during the electrode placement, stimulation, or neurotomy.

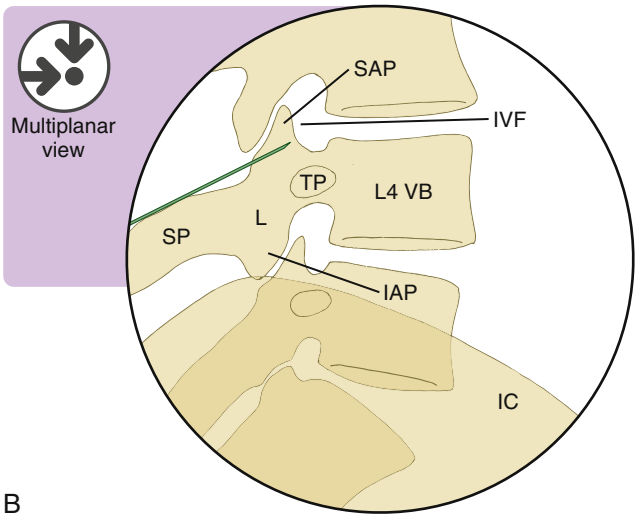
Fig. 15C.3. A, Fluoroscopic image of an anteroposterior view with the radiofrequency electrode tip in position over the right L3 medial branch nerve. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view. Please see Figs. 15E.1 and 15E.2 for additional details about Z-joint anatomy/innervation and ideal radiofrequency electrode placement.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 15C.4)

Check the lateral view to confirm that the needle tip is located posterior to IVF. The C-arm should be oriented to obtain a true lateral view (see Chapter 3). Stay along the base of SAP to remain superior to MAL (Fig. 15C.4C) for the L1 to L4 medial branches. Note that MAL at the L5 segment is rudimentary and, thus, permits a more sagittal approach for the L5 dorsal ramus.



A



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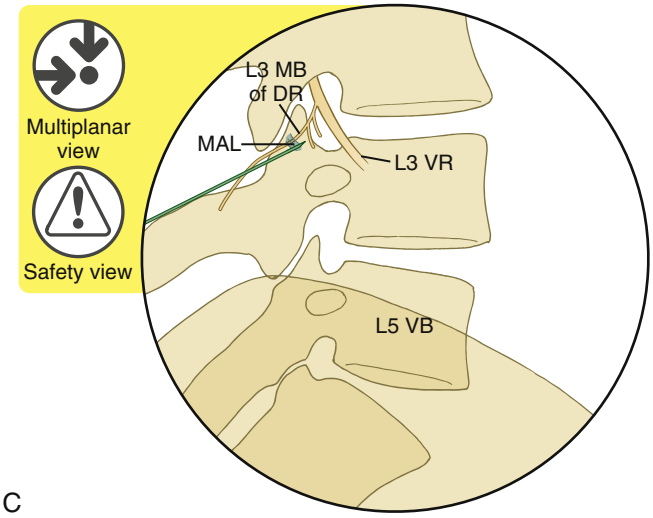


C

Lateral View Safety Considerations

- Confirm that the radiofrequency electrode is not too ventral (i.e., not located in the IVF where the ventral ramus lies or in the intervertebral disc space).
- Reposition the radiofrequency electrode if the patient complains of paresthesias or pain radiating to the lower limb during the electrode placement, stimulation, or neurotomy.

Fig. 15C.4. A, Fluoroscopic image of a lateral view with the radiofrequency electrode in position over the right L3 medial branch nerve. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view. Please see Figs. 15E.1 and 15E.2 for additional details about Z-joint anatomy/innervation and ideal radiofrequency electrode placement.

Notes on Needle Positioning in the Multiplanar Views

Please see Figs. 15E.1 and 15E.2 for diagrams and figures depicting position of the medial branches and dorsal rami and associated radiofrequency electrode positions and lesion zones in multiple views.

Optimal Position View (Fig. 15C.5)

Contrast is typically not used during radiofrequency denervation.

Electrode tip position is crucial to cover the maximal portions of the medial branch or dorsal ramus. Please see Figs. 15E.1 and 15E.2 for the representation of ideal radiofrequency electrode placement.

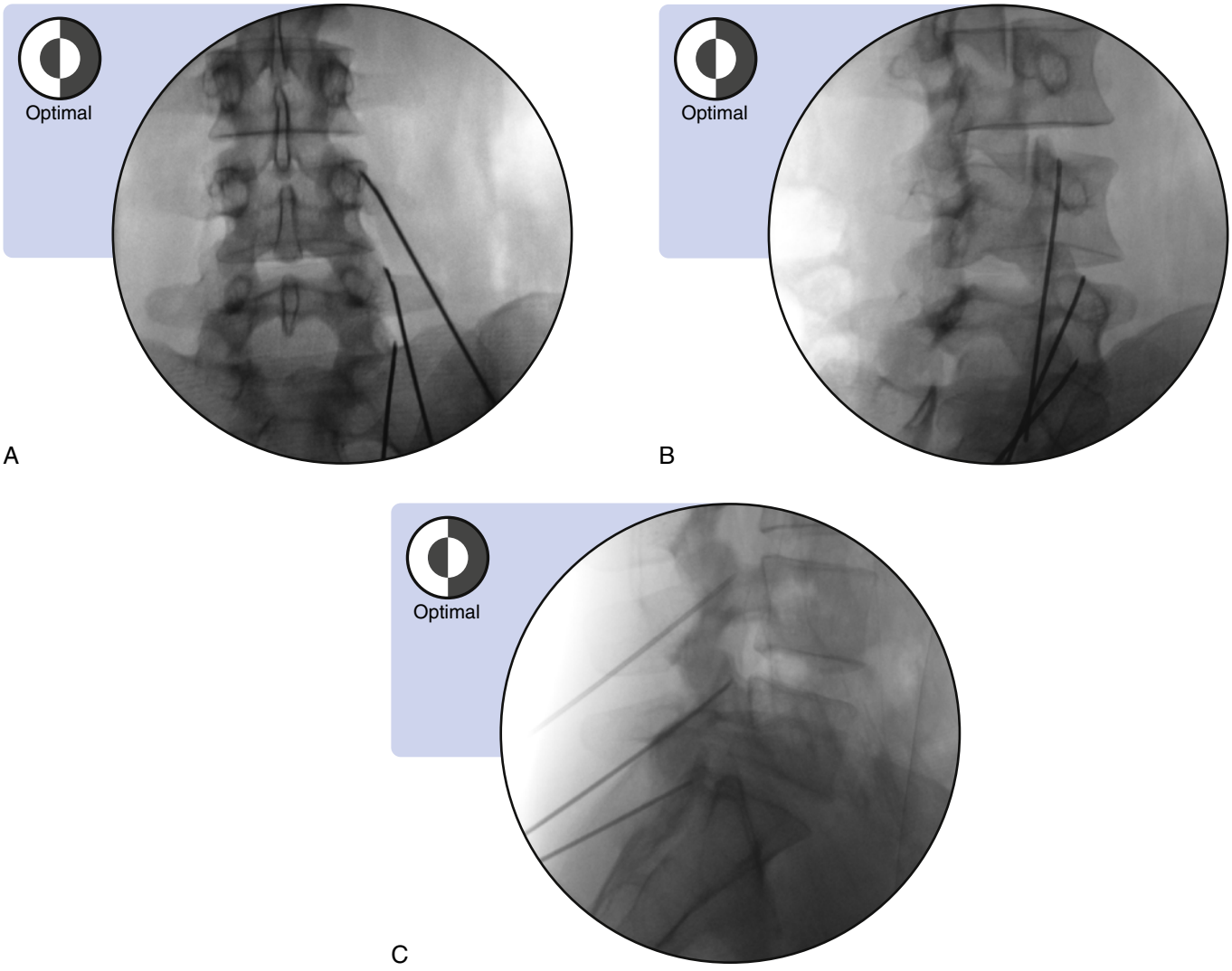


Fig. 15C.5. A, AP, **B,** oblique, and **C,** lateral fluoroscopic images of the radiofrequency electrode tips in position over the right L3 and L4 medial branches and L5 dorsal ramus. Please see Figs. 15E.1 and 15E.2 for additional details about Z-joint anatomy/innervation and ideal radiofrequency electrode placement.

Suboptimal Position Views (Figs. 15C.6 and 15C.7)

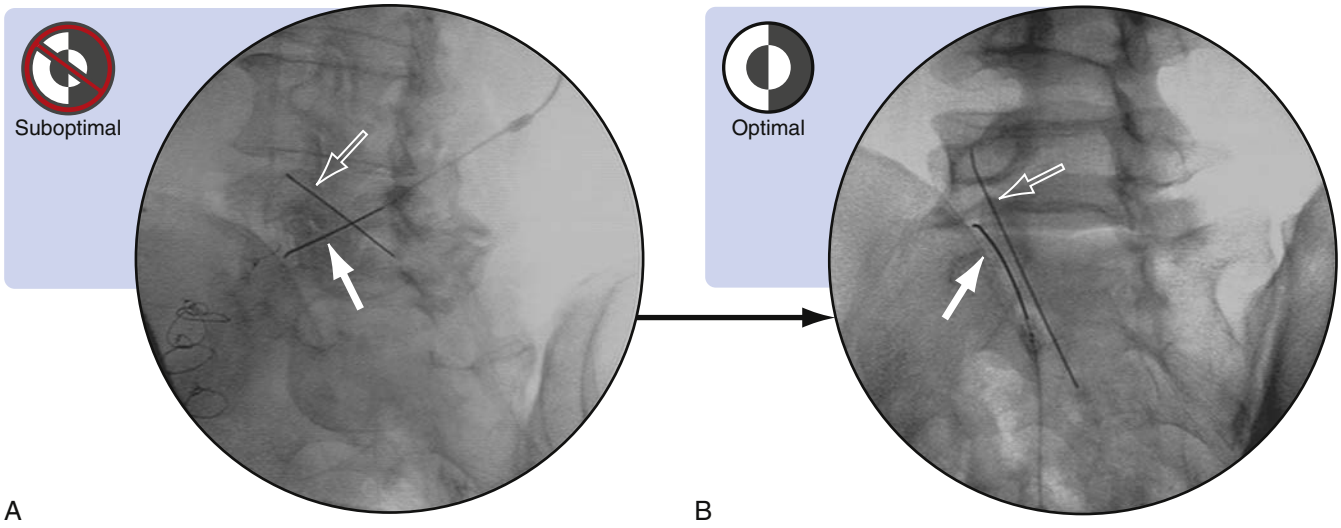


Fig. 15C.6. A, Fluoroscopic image of an ipsilateral oblique view with radiofrequency electrode tips in a suboptimal position for the denervation of the L4 medial branch and L5 dorsal ramus nerves. The radiofrequency electrode tips are not placed at the lateral border of the superior articular process and the concavity that is formed by the junction of the superior articular process and transverse process. The L4 radiofrequency electrode tip (open arrow) is located too lateral, and the L5 radiofrequency electrode tip (closed arrow) is located too superior to its target. **B,** Fluoroscopic image of an oblique view with the radiofrequency electrode tips in an optimal position for the neurotomy of the L4 medial branch (open arrow) and L5 dorsal ramus (closed arrow) nerves (in a different patient from the one depicted in part A of this figure). The tips are placed at the lateral border of the superior articular process and the concavity that is formed by the junction of the superior articular process and transverse process. The L4 medial branch electrode is slightly lateral to the most optimal location. Since most practitioners perform neurotomy a minimum of two times at each site, the location of the L4 radiofrequency electrode tip would be sufficient for one of the neurotomy sites. Another placement should be more medial and closer to the SAP/transverse process junction.

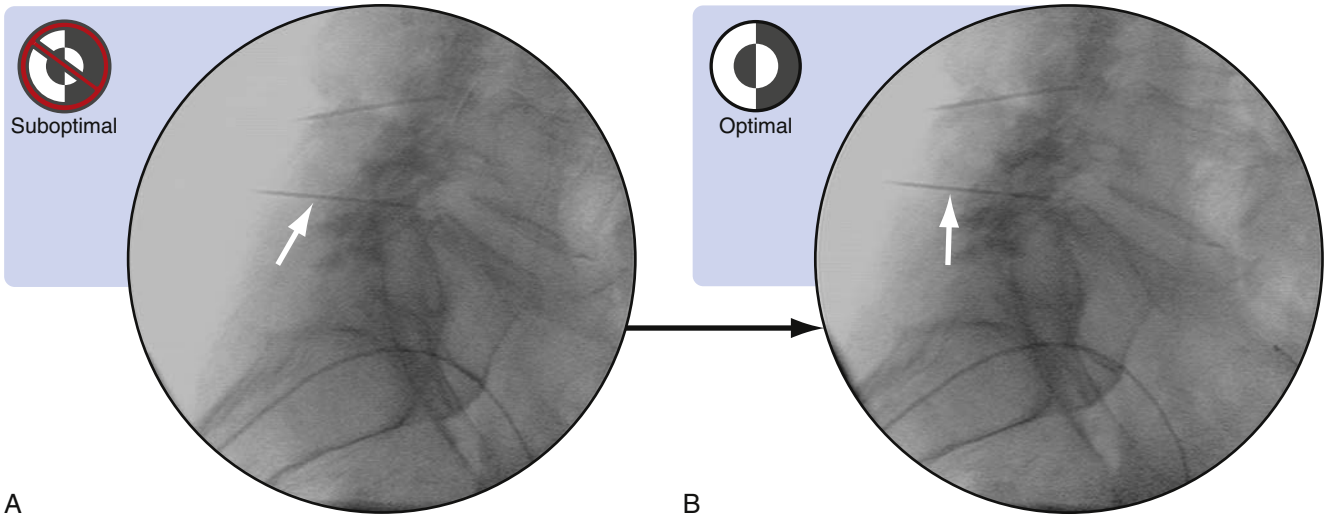


Fig. 15C.7. A, Fluoroscopic image of a lateral view with the inferior radiofrequency electrode tip (arrow) in a suboptimal position for the denervation of the L5 dorsal ramus. The radiofrequency electrode tip is ventral to the posterior aspect of the intervertebral foramen, which may potentially unintentionally injure the exiting L5 spinal nerve; this is highly undesirable. **B,** Fluoroscopic image of a lateral view with the inferior radiofrequency electrode tip pulled back to an optimal position for the neurotomy of the L5 dorsal ramus. The radiofrequency electrode tip is located posterior to the intervertebral foramen.

Video 15C.1 Video demonstrating an alternative technique to obtain a trajectory view for L1 to L4 medial branches. After lining up the superior end plate, oblique 20 degrees ipsilaterally. Caudally tilt the C-arm and enter one level inferiorly using this alternate trajectory view.

Video 15C.2 Video demonstrating an alternative technique to obtain a trajectory view for the L5 dorsal ramus. No oblique is used. Mark the target one segment inferiorly, and tilt the C-arm caudally with the electrode entering one level inferiorly using this alternate trajectory view..

References

1. Gofeld M, Faclier G. Radiofrequency denervation of the lumbar zygapophysial joints—targeting the best practice. *Pain Med*. 2008;9(2):204–211.
2. Bogduk N, ed. International Spinal Intervention Society practice guidelines for spinal diagnostic and treatment procedures; lumbar spinal nerve blocks. 2nd ed. San Francisco, Ca: International Spine Intervention Society; 2013.

CHAPTER 15D

Lumbar Medial Branch Blocks—Midline: Ultrasound Guidance

Louis Torres, Paul S. Lin, and Michael B. Furman

Performing diagnostic medial branch blocks with ultrasound guidance is an alternative method to the fluoroscopic technique. Theoretically, using ultrasound guidance negates the need of fluoroscopy, can help avoid unnecessary radiation exposure to both patient and physician, and can be just as accurate as fluoroscopically guided medial branch blocks.

The ultrasound-guided lumbar medial branch block will be described using an in-plane technique with an out-of-plane confirmation. This approach is the most convenient and the least technically demanding and allows one to accurately and consistently reach the target point.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 15D.1)

- Prone patient in optimal position.
- Ultrasound unit positioned on the side opposite to the interventionist and in line with the transducer (see 15D.1A and Chapter 4).
- Utilize a curvilinear transducer to better visualize the deeper spinal structures.
  - Begin by placing the transducer in axial orientation over the sacrum, and scan cephalad to get to the desired lumbar levels (see Chapter 4).
- Obtain an axial view of the desired lumbar vertebrae, with the spinous process midline. Translate the probe laterally to the target side, and center the probe over the junction of superior articular process (SAP) and transverse process (TP).
- Translate cephalad to identify the superior border of TP.
- For the L1 to L4 medial branches, the target needle destination is at the junction of SAP and TP, where the target nerve crosses midway between the superior border of TP and the mamillo-accessory ligament (MAL) notch.
- For the L5 dorsal ramus, the nerve courses over the ala of the sacrum on a path similar to the L1 to L4 medial branches. The target point is located at the middle of the base of SAP, and therefore, slightly below the sacral ala. If the iliac crest interferes with the placement of the needle at the L5 dorsal ramus, rotate the probe to obtain an unobstructed needle path.
- Using a lateral to medial approach, target the needle tip to the SAP and TP junction.

Fig. 15D.1. A, Suggested room setup for ultrasound guided lumbar medial branch block.

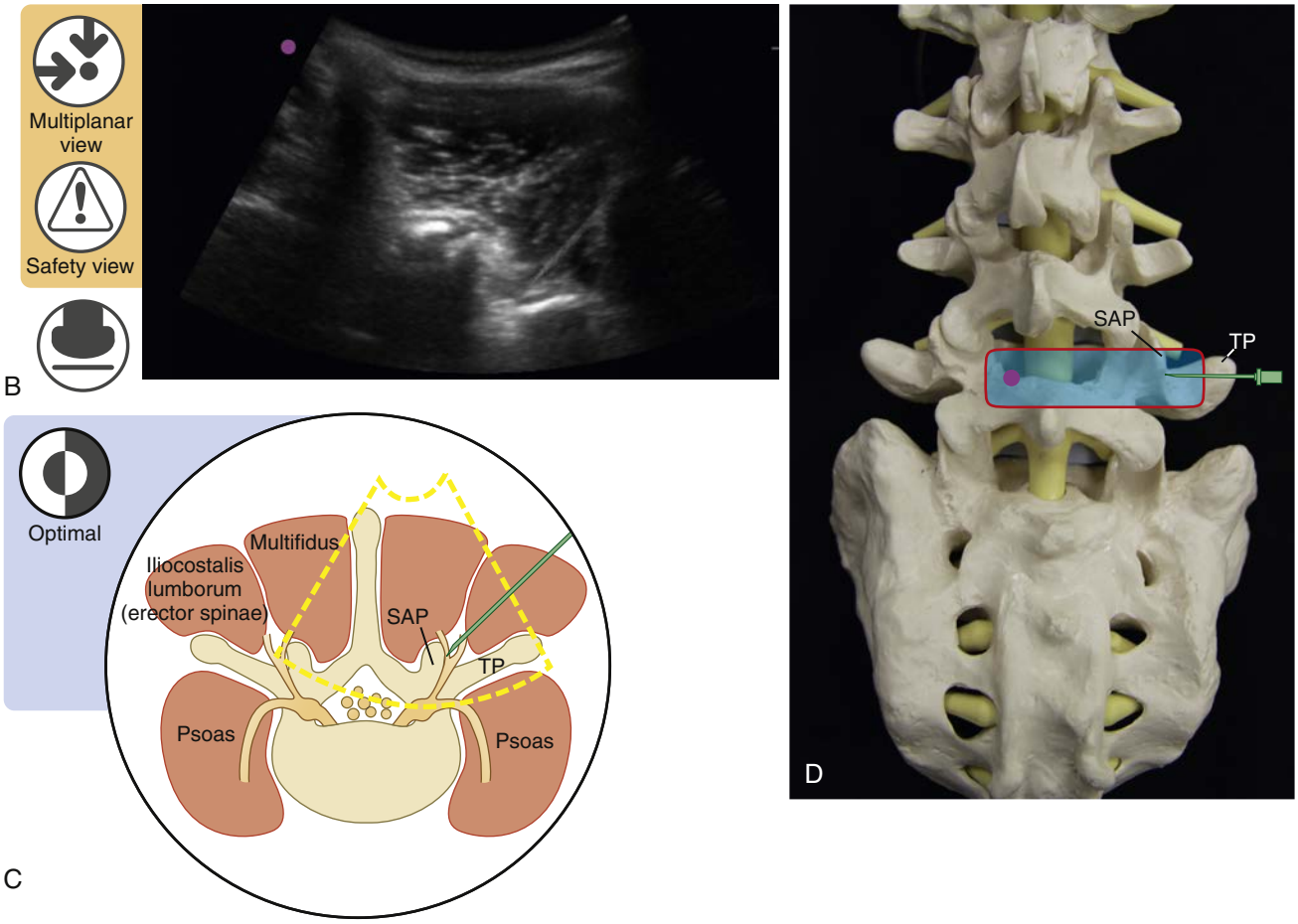


Fig. 15D.1, cont'd B, Ultrasound image of spinal needle placement at the superior articular process (SAP) and transverse process (TP) junction, in-plane.**C,** Drawing of relevant radiolucent structures. Yellow dashed line represents borders of the image seen on ultrasound in part A. **D,** Skeleton with probe. Proper placement of ultrasound probe for long axis confirmation. The rectangle outlines the area that the curvilinear probe visualizes.

In-Plane Technique Safety Considerations

Maintain visualization of the entire needle over osseous structures to avoid nerves, discs, and epidural space.

Out-of-Plane Confirmation (Fig. 15D.2)

- Rotate the probe 90 degrees to obtain an out-of-plane confirmation.
  - This view is used to visualize the needle tip at the junction of the SAP and superomedial border of TP.
  - The needle will appear as a single dot, as demonstrated in Fig. 15D.2A.
    - Needle rotation or "jiggle" can help visualize the needle in the out-of-plane confirmation.

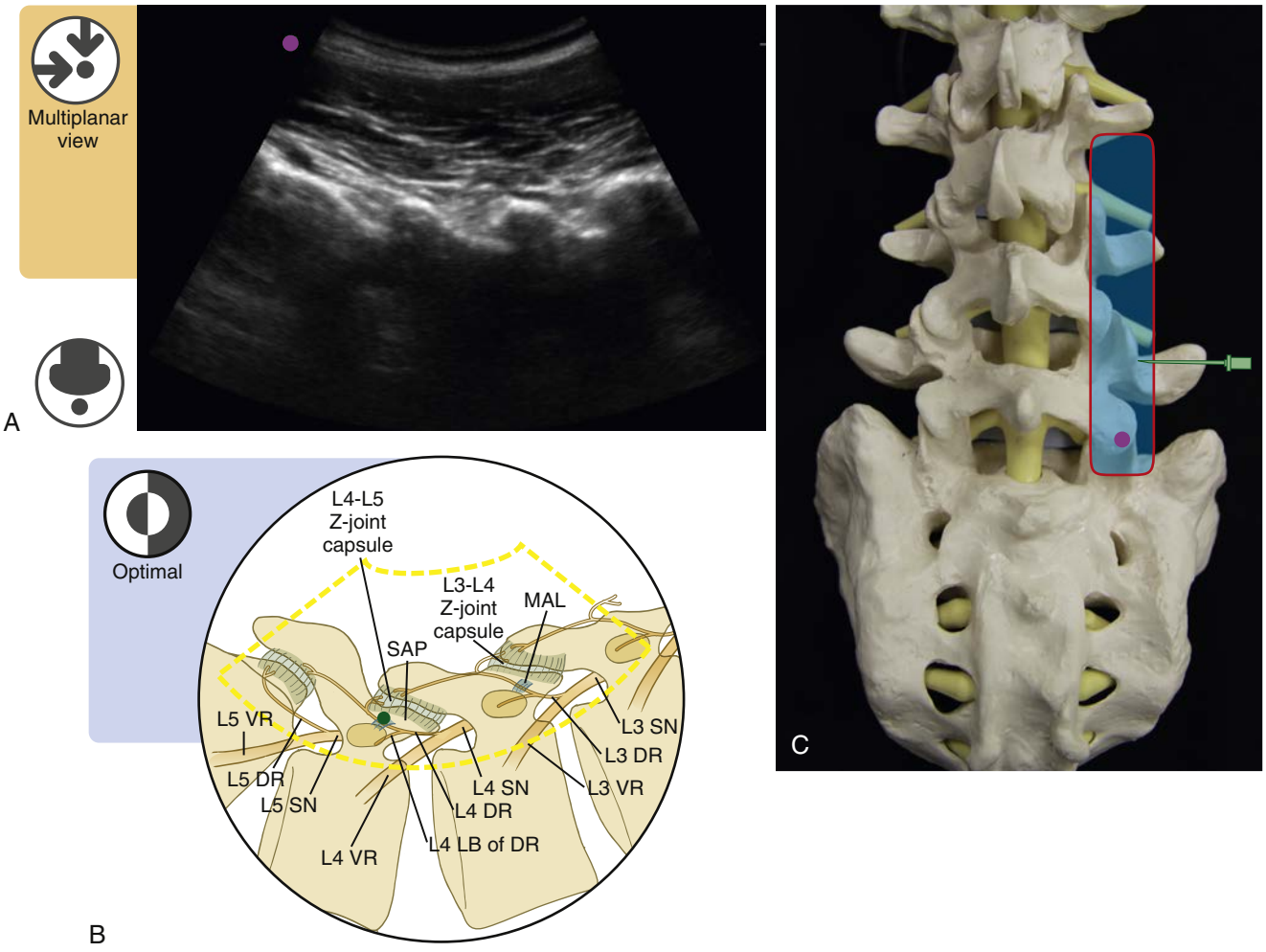


Fig. 15D.2. **A**, Out-of-plane para-sagital ultrasound image overlying the zygopophysial joints, with needle placement at the junction of the superior articular process (SAP) and transverse process (TP). **B**, Drawing of relevant radiolucent structures. Yellow dashed line represents borders of the image seen in part A. **C**, Skeleton with probe. Proper placement of ultrasound probe for an out-of-plane confirmation. The rectangle outlines the area that the curvilinear probe visualizes.

There are typically no safety considerations in this view. Please use the in-plane view for needle advancement to best visualize the corresponding landmarks.

Reference

1. Greher M, Kirchmair L, Enna B, et al. Ultrasound-guided lumbar facet nerve block: accuracy of a new technique confirmed by computed tomography. *Anesthesiology*. 2004;101(5):1195–1200.

CHAPTER 15E

Lumbar Zygapophysial Joint Innervation, Anatomy, Dissections, and Lesion Zone Diagrams

Luis Baez-Cabrera, Jason G. Anderson, Brian F. White, and Michael B. Furman

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

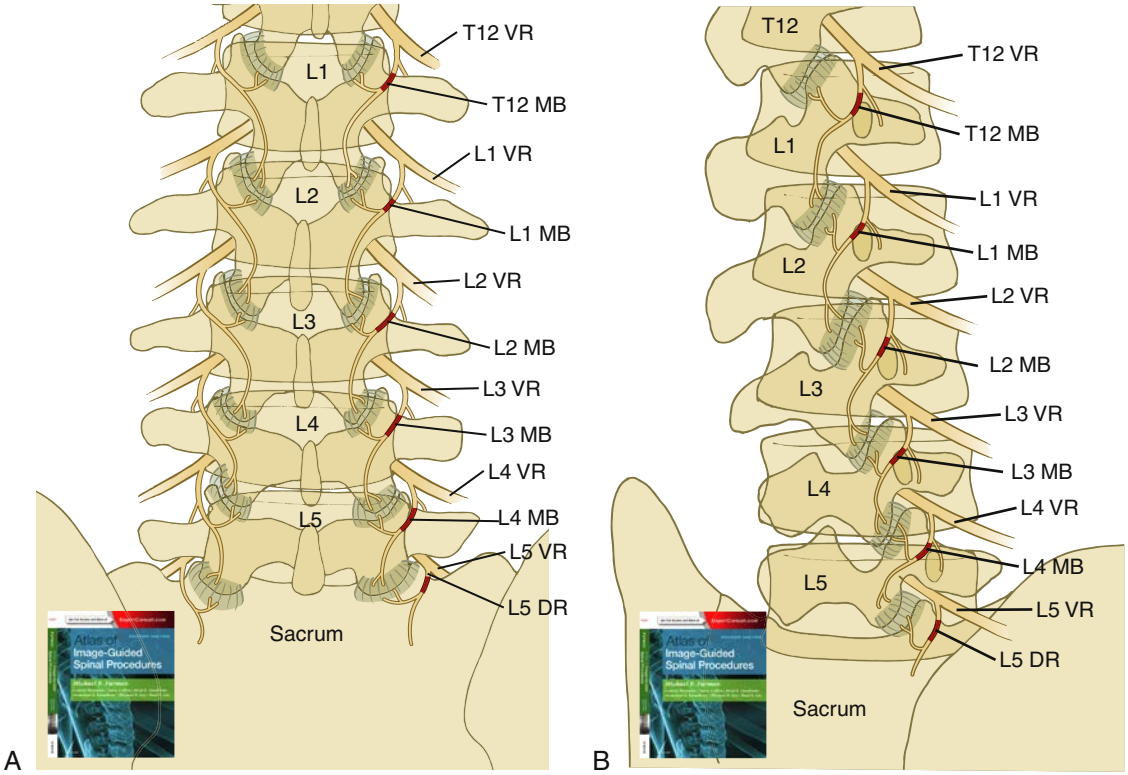


Fig. 15E.1. The Z-joints are innervated by two lumbar medial branches (MB) of the dorsal rami. Both MBs must be anesthetized to achieve the diagnostic block of the associated zygapophysial joint. The target for blockade or neurotomy is the red region illustrated on the respective nerves. MB nerves are not labeled for the transverse process (TP) that they cross but rather for their originating spinal nerves. Using this nomenclature the L3 MB travels across the L4 TP at the base of the L4 SAP. The L4-L5 Z-joint would therefore be blocked by anesthetizing MBs L3 and L4. The L5-S1 Z-joint is a special case in which the L4 MB and the L5 dorsal ramus (DR) are anesthetized. **A,** Anteroposterior (AP) view. **B,** Oblique view. (For a high-resolution version of this image, go to www.expertconsult.com.)

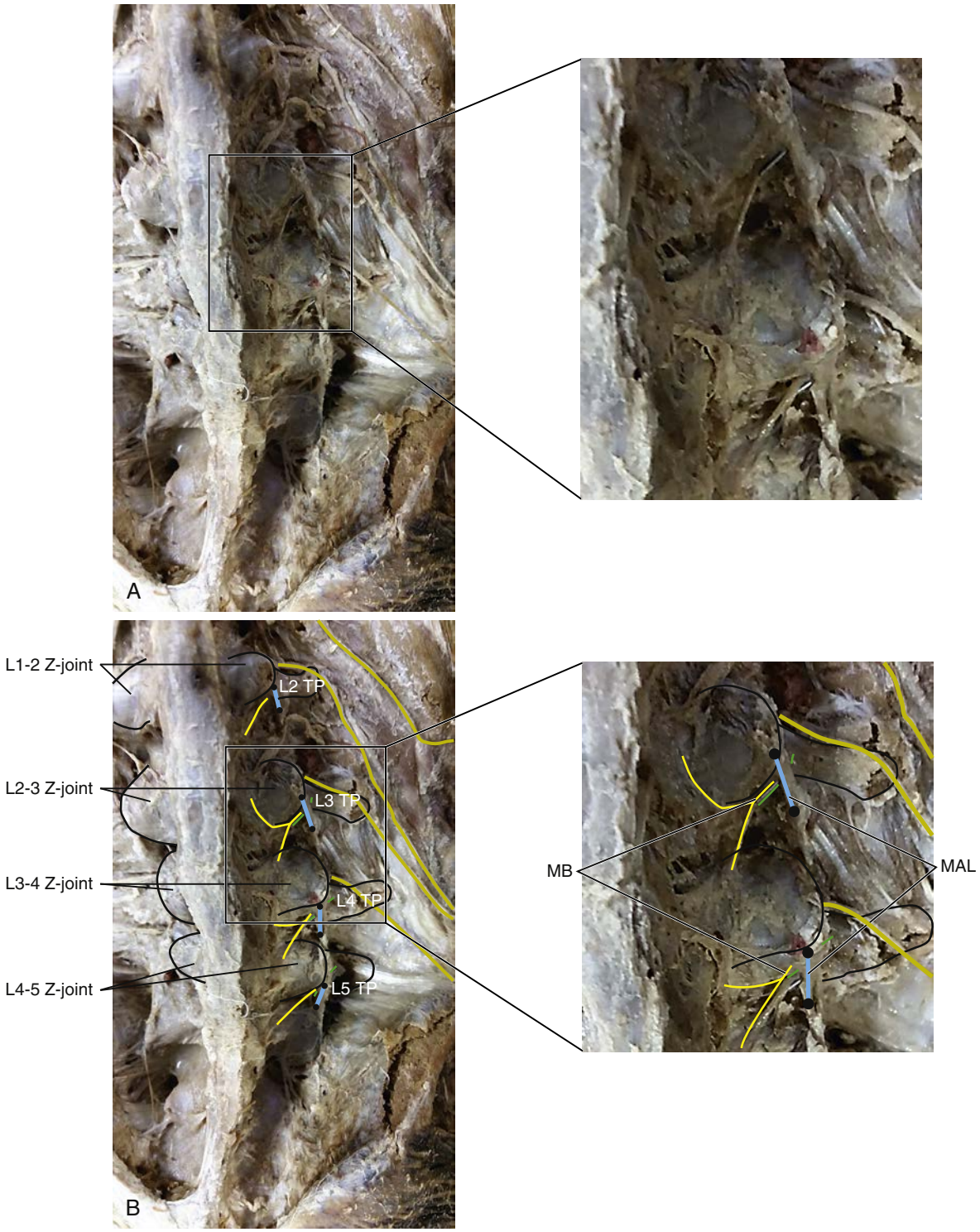


Fig. 15E.2. A and B, Cadaveric dissection of the lumbar spine. Images viewed from near AP perspective with ~10 degrees of right oblique. **A,** Unlabeled view. Posterior capsule of lumbar zygapophysial joint (Z-joint), lumbar transverse processes (TP), mamillo-accessory ligament (MAL), medial branch (MB), and lateral branch (LB) are all visible in dissection. Also visible are short wire segments placed in close approximation to the L2, L3, and L4 medial branches in their course underneath the MAL. The superior attachment of the MAL at the mamillary process, located at the inferior posterior aspect of the superior articular process (SAP), as well as the inferior attachment of the MAL at the accessory process located at the posterior aspect of the proximal portion of the transverse process are both also visible. **B,** Labeled view. Black lines outline the posterior view of the lumbar Z-joints and transverse process. Blue lines demonstrate the position of the MAL at each level. Black dots represent the superior attachment of the MAL at the mamillary process and the inferior attachment at the accessory process. Bright yellow lines highlight the course of the MBs as they emerge from underneath the MAL and course toward their targets in the facet capsules. Green lines highlight the position of the wire segments placed along the course of the MBs. Gold lines demonstrate the course of the lateral branches of the dorsal rami along the transverse process and extending distally. Cadaveric specimens and dissection provided courtesy of Professor Frank Willard and the Anatomy Department of New England College of Osteopathic Medicine, Beddeford, ME.

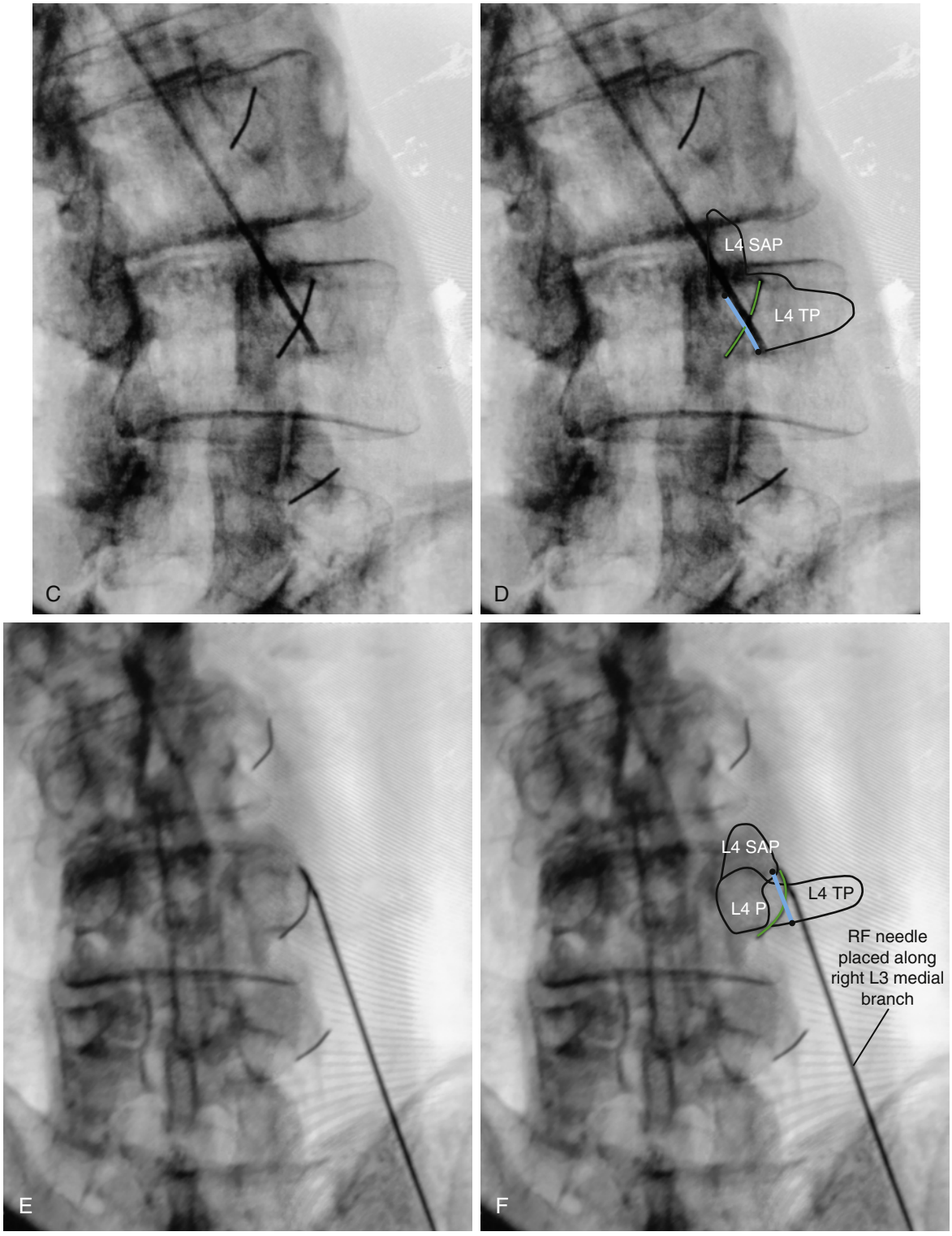


Fig. 15E.2. cont'd C–F Right oblique and AP fluoroscopic images of the cadaveric dissection viewed in Fig. 15E.2 **A** and **B. C,**. Unlabeled right oblique view. Image demonstrates the position of the L4 MAL in an oblique fluoroscopic view. A metal probe has been placed across the right L4 MAL in figures **C** and **D**. The distal tip of the probe lies directly over the right L4 mamillary process at the base of the right L4 SAP. **D,** Labeled right oblique view. Black line outlines the right L4 SAP and TP. Black dots demonstrate the location of the proximal attachment of the right L4 MAL at the mamillary process at the base of the SAP and the distal attachment at the accessory process on the proximal inferior transverse process. Blue line highlights the course of the L4 MAL. A green line demonstrates the position of the wire segment placed in close approximation to the L3 medial branch along its course deep to the L4 MAL. AP fluoroscopic views (**E** and **F**) are presented with radiofrequency probe positioned in typical placement for a L3 medial branch radiofrequency (RF) neurotomy. See Chapter 15C for details on medial branch radiofrequency neurotomy. **E** unlabeled and **F** labeled. Images demonstrate the position of an appropriately placed RF probe along the course of the right L3 medial branch (MB) with the active tip of the probe place at the intersection of the base of the L4 superior articular process (SAP) and the L4 transverse process (TP) in an AP fluoroscopic view. Wire segment is visualized long the course of the MB at the L3 target level (green) as well as along the course of the right L2 and L4 MBs. Black lines outline the position of the right L4 SAP, pedicle (P), and TP in an AP fluoroscopic view. Blue line represents position of the L4 MAL. Green line demonstrates the positon of wire segment placed along the course of the right L3 MB in the cadaveric specimen.

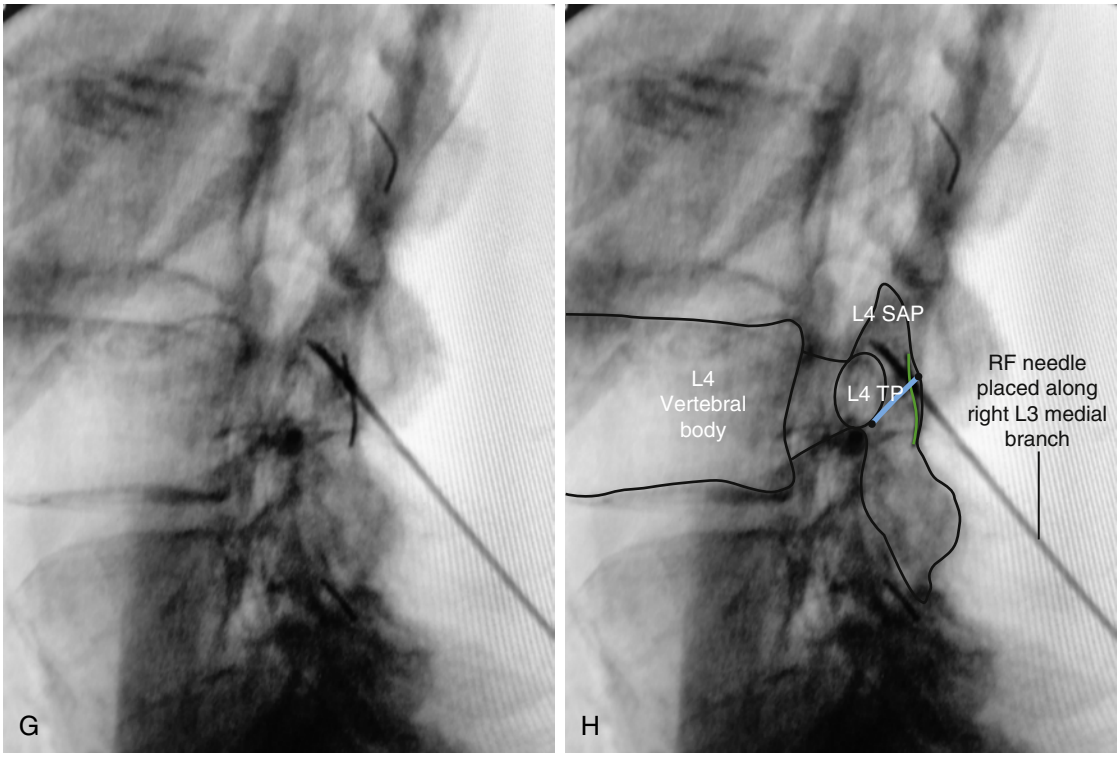


Fig. 15E.2. cont'd G and H, Fluoroscopic lateral images of the cadaveric dissection specimen viewed in **A** and **B**., **G** unlabeled and **H** labeled. Images demonstrate the position of an appropriately placed RF probe along the course of the right L3 MB with the tip of the probe place at the intersection of the base of the L4 SAP and the L4 TP in a lateral fluoroscopic view. Wire segments are visible at the right L2, L3, and L4 level MBs. RF needle placed along the course of the right L3 MB (green) with final placement of the active needle tip at the base of the right L4 SAP along the superior margin of the right L4 TP. Note that the TP is viewed "end on" and has an elliptical shape. Since the base of the TP is larger than the tip, the probe appears to rest slightly superior to the L4 TP. However, the RF needle is actually placed in close approximation to the periosteum along the superior margin of the TP at the base of the TP. Black lines outline the L4 vertebral body, SAP, and TP. Blue line represents the positon of the MAL. Green line demonstrates the positon of wire segment placed along the course of the right L3 MB in the cadaveric specimen.

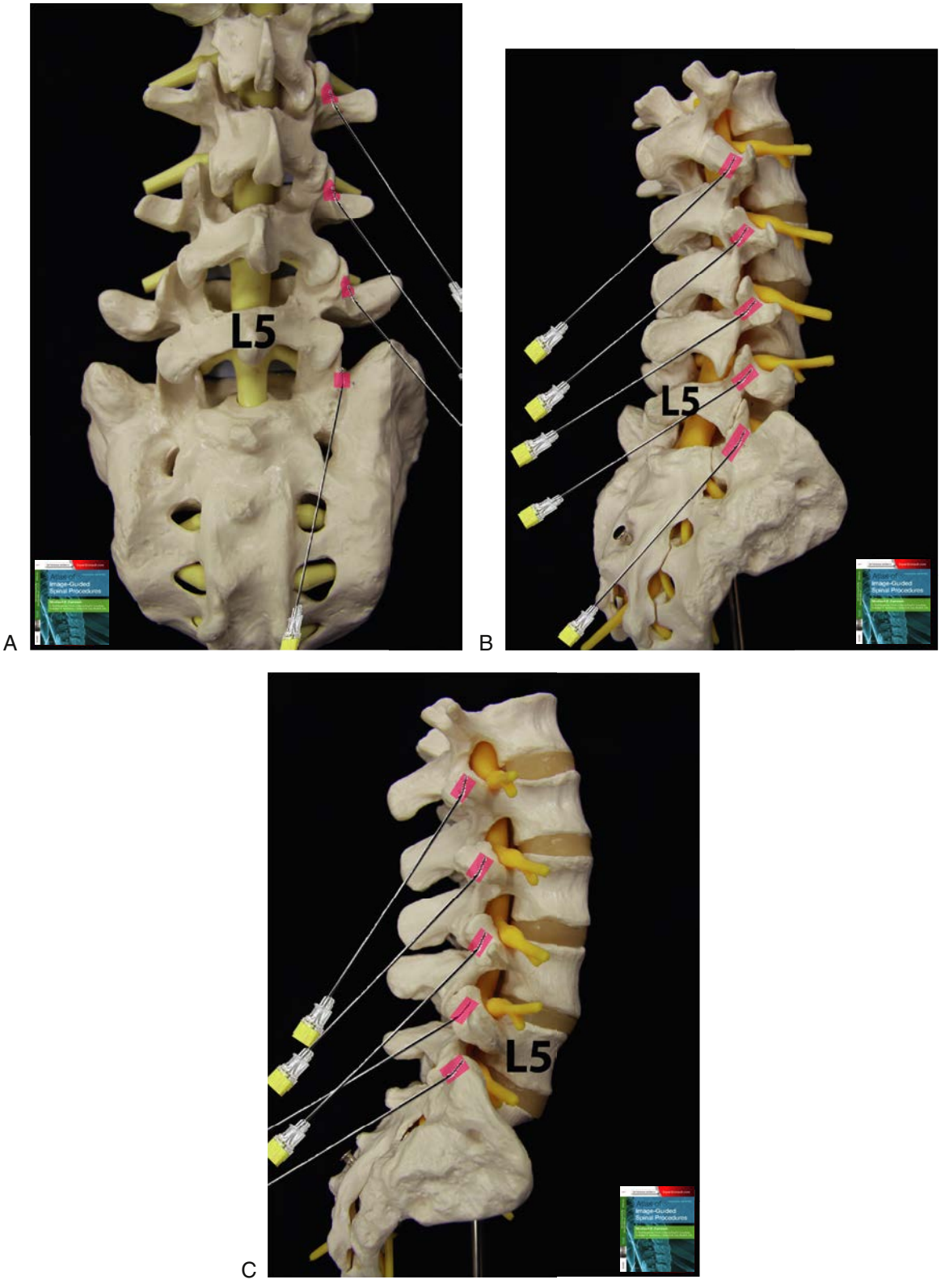


Fig. 15E.3. Illustration and model of an idealized lumbar spine with RF electrode positioning and lumbar medial branch (MB) and L5 dorsal ramus (DR) lesions. The target "zone" for neurotomy is demonstrated as a pink region based on and extrapolated from a known MB anatomy demonstrated and referenced in Fig. 15E.1. **A,** Anteroposterior (AP) view. **B,** Oblique view. **C,** Lateral view. (For a high-resolution version of this image, go to www.expertconsult.com.)

CHAPTER 16

Lumbar Sympathetic Block

Jonathan B. Stone, James J. Gilhool, and Michael B. Furman

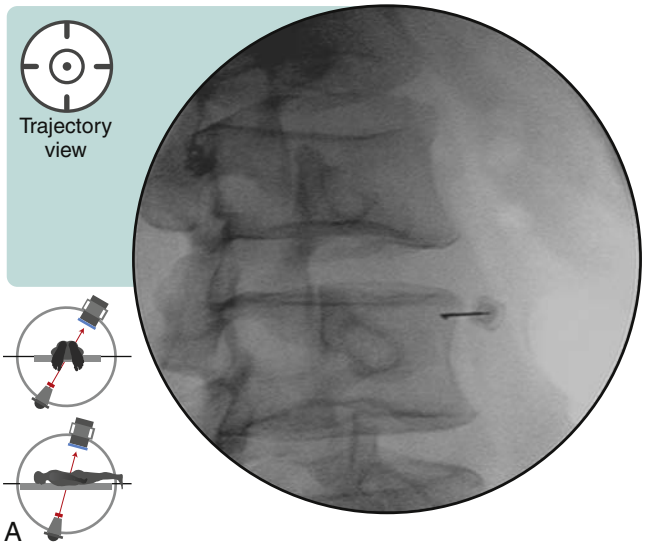
Sympathetic nerve blocks are used to help with the diagnosis and treatment of sympathetically maintained pain. The lumbar sympathetic chain typically overlies the anterolateral aspect of the first through fourth lumbar vertebrae. The axons of the lumbar sympathetic preganglionic neurons exit the spinal cord through the ventral roots of the first four lumbar spinal nerves and send fibers through the white rami communicantes to the corresponding lumbar sympathetic ganglia. Postganglionic fibers then exit the chain to join a vascular plexus or the spinal nerves via the gray rami communicantes. The largest portion of lumbar sympathetic ganglia is located in the area of the second and third lumbar vertebrae. Therefore, a single-level block along the lower third of L2 or the upper third of L3 is usually sufficient as long as there is adequate medication spread. This chapter describes an injection at the L3 level.

A successful response to lumbar sympathetic nerve blocks includes an increase in temperature of at least 2°C, vasodilation, and a decrease in pain on the injected side's lower limb. The diagnostic yield is greatly improved with therapy scheduled immediately after the procedure for a functional reassessment and more aggressive treatment.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

- **Confirm the level** with the anteroposterior view.
- **Tilt the fluoroscope's image intensifier cephalad or caudad** (Fig. 16.1).
- The lumbar sympathetic chain overlies the anterolateral aspect of the first through fourth lumbar vertebrae.
- Line up the superior vertebral end plate of L3.
- **Oblique the fluoroscope** ipsilaterally until the tip of the transverse process is in line with the anterior aspect of the vertebral body.
- The target needle destination is at the inferior portion of the L2 vertebral body or the superior portion of the L3 vertebral body (shown).
- Aim toward the anterior aspect of the vertebral body.
- **Place the needle** parallel to the fluoroscopic beam.



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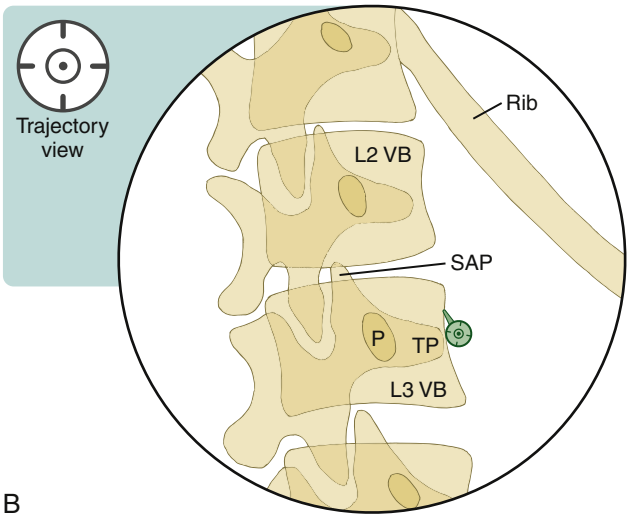

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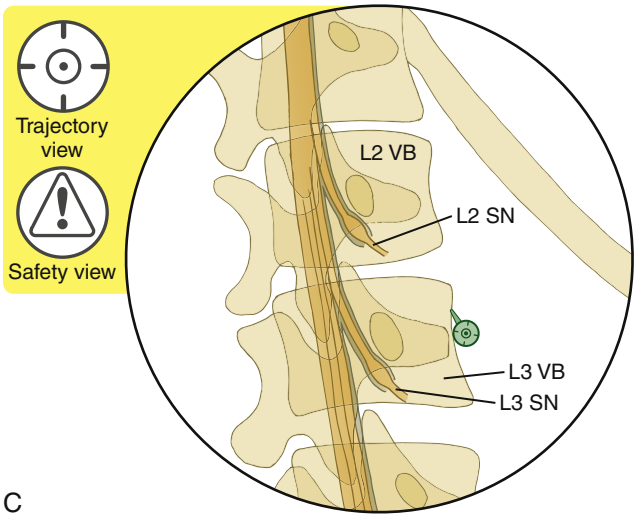


C

Trajectory View Safety Considerations

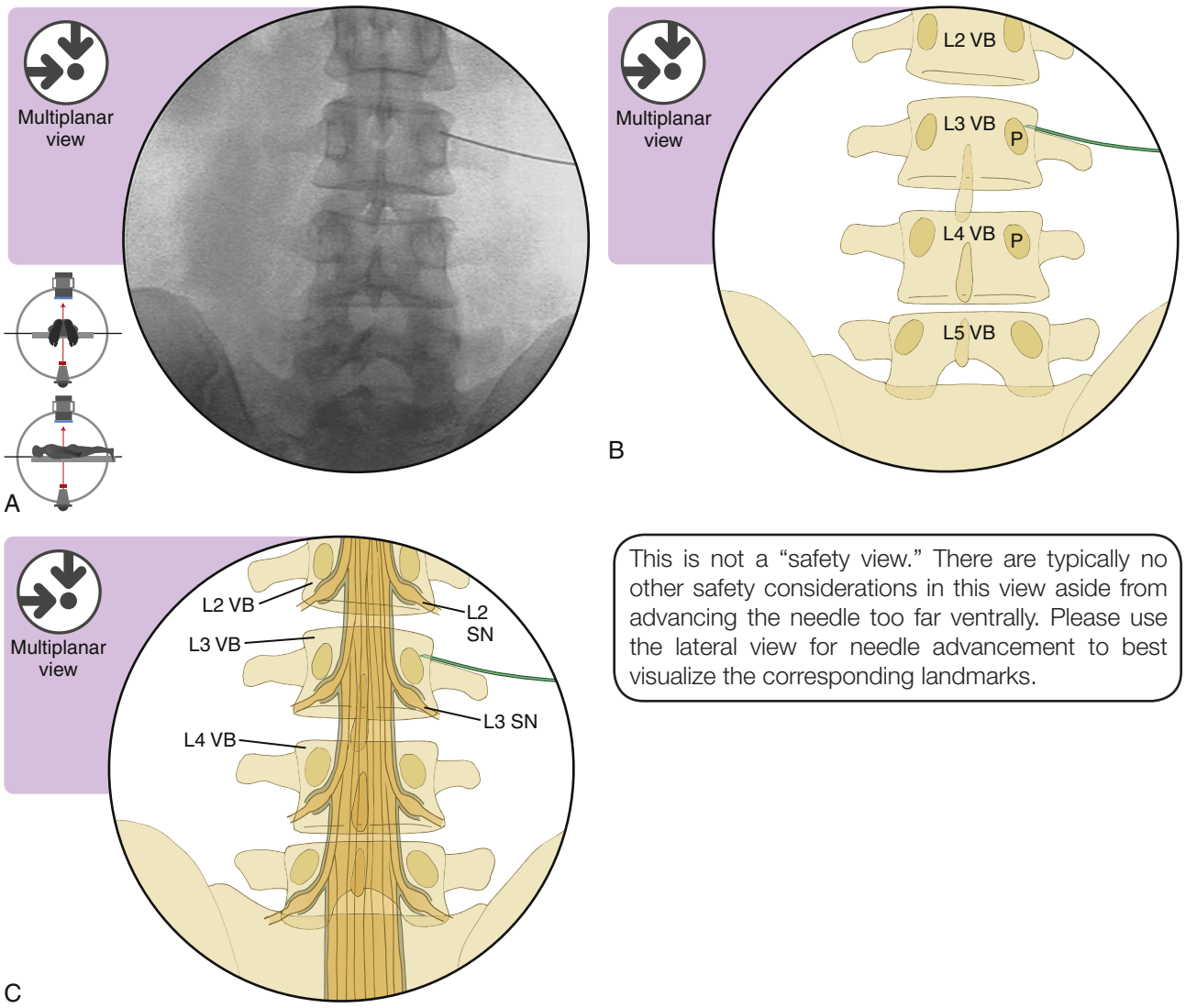
Avoid piercing the exiting spinal nerve by placing the needle superolateral to the L3 transverse process.

Fig. 16.1. A, Fluoroscopic image of a trajectory view with the needle in position at the superior portion of the L3 vertebral body. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

Optimal Needle Positioning in the Anteroposterior View (Fig. 16.2)

- After the needle is placed in the trajectory view, oblique the C-arm back for a "true" fluoroscopic anteroposterior view with the ideal needle position.
- The needle should ideally approach the midpedicular position. This can be fine-tuned after the needle depth is verified by a lateral view.
- As the needle is advanced, it should be in contact with (walked along) the vertebral body and adjusted accordingly to achieve proper placement.



This is not a "safety view." There are typically no other safety considerations in this view aside from advancing the needle too far ventrally. Please use the lateral view for needle advancement to best visualize the corresponding landmarks.

Fig. 16.2. A, Fluoroscopic image of an anteroposterior view of the L3 vertebral body with the ideal needle tip position for a sympathetic block. The needle tip is approaching the midpedicular position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 16.3)

- When the needle is placed with the help of the trajectory view and confirmed with the anteroposterior view, then a lateral image is obtained. The lateral view is the true **safety view,** and it is used to verify the needle depth.
- The C-arm should be oriented to obtain a "true" lateral view (see Chapter 3).
- The needle should be adjusted so that the tip is 3 to 5 mm dorsal to the most ventral aspect of the vertebral body.

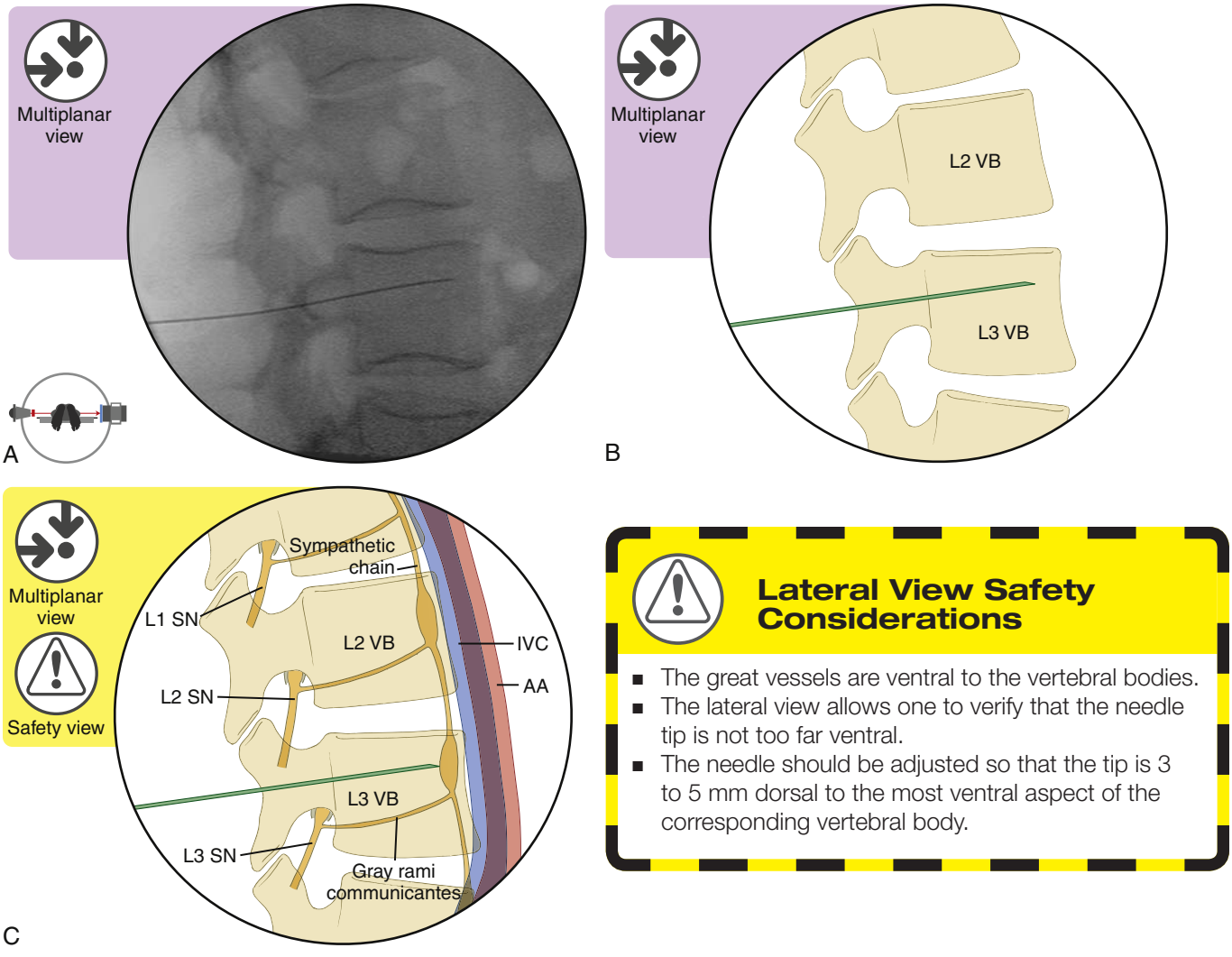


Fig. 16.3. A, Fluoroscopic lateral view with the ideal needle position for a sympathetic block. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Contrast Pictures (Figs. 16.4 and 16.5)

Optimal Image

- Ideal flow should surround the anterior aspect of the vertebral body by spreading superiorly and inferiorly and covering ideally from L1 to L3.

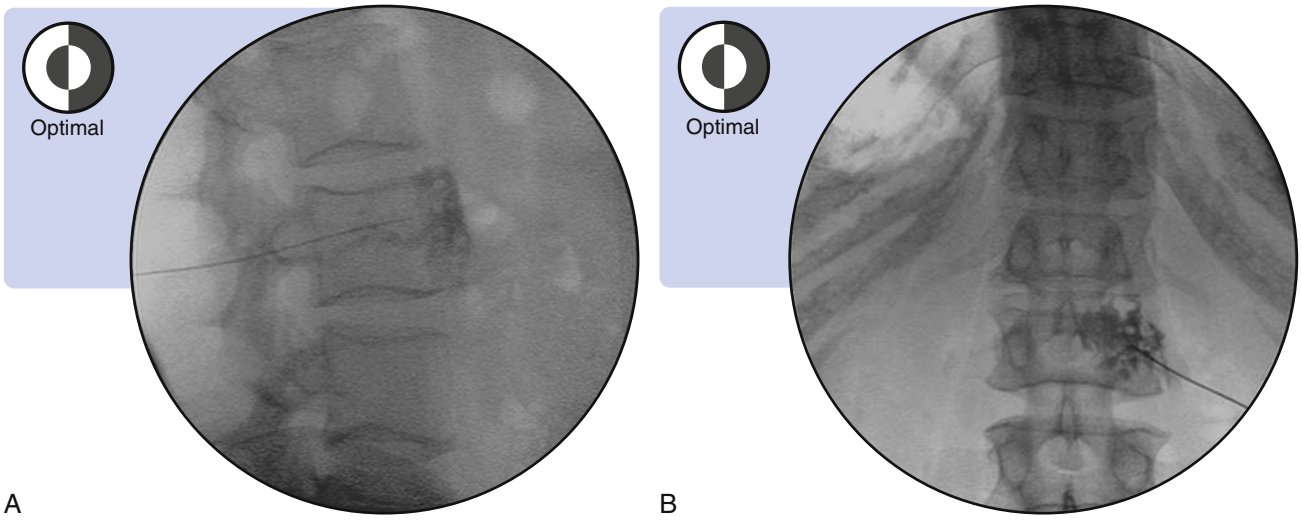


Fig. 16.4. **A,** Lateral fluoroscopic image of a lumbar sympathetic nerve block with 0.5 cc of contrast medium at the superior portion of the L2 vertebral body. **B,** Anteroposterior (AP) fluoroscopic image of a lumbar sympathetic nerve block within 3 to 5 mm of the anterior aspect of the L2 vertebral body with contrast. Final needle placement should actually be slightly more caudad; however, there is optimal contrast flow inferior to the target.

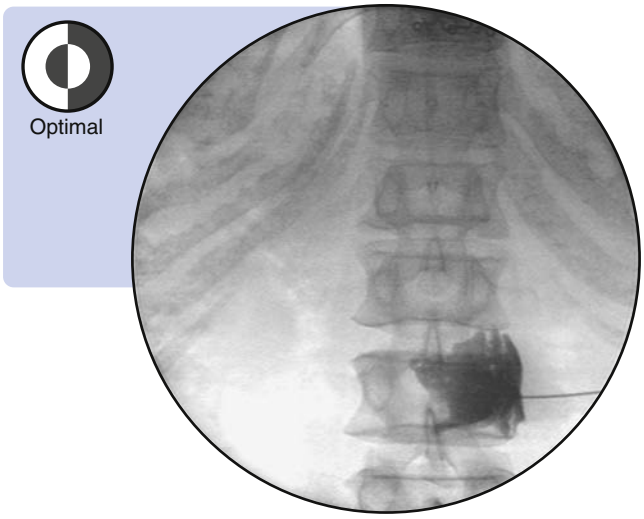


Fig. 16.5. Anteroposterior fluoroscopic image of a lumbar sympathetic block at the right L3 level with optimal contrast.

Suboptimal Images (Figs. 16.6 and 16.7)

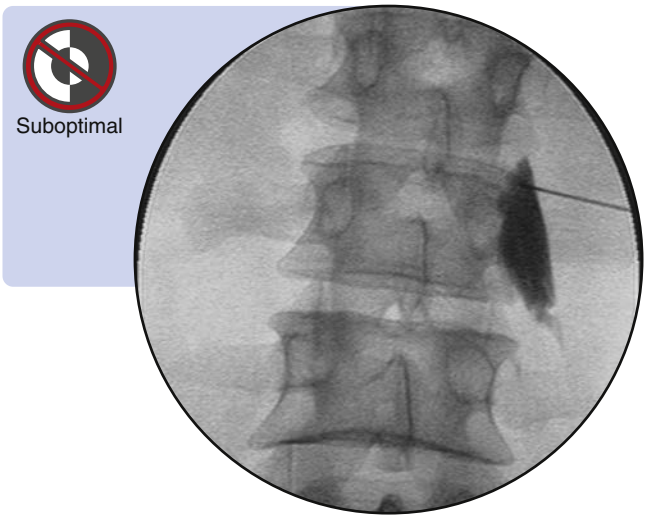


Fig. 16.6. Suboptimal flow that demonstrates a fascial pattern, with amorphous contrast spread into the soft tissues not covering the sympathetic chain.

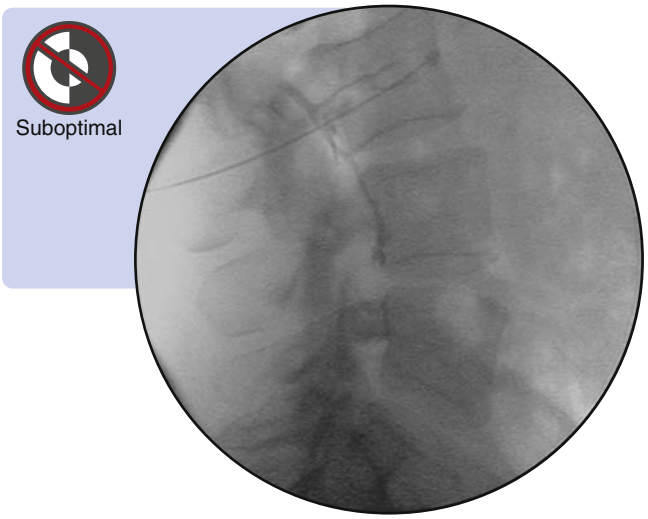


Fig. 16.7. Suboptimal flow in a lateral view that demonstrates a vascular pattern. Although the image is static, when observed under live fluoroscopy, the contrast rapidly dissipates.

Suggested Readings

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2. Rocco AG, Palombi D, Raeke D. Anatomy of the lumbar sympathetic chain. *Reg Anesth*. 1995;20(1):13–19.

CHAPTER 17

Lumbar Provocation Discography/Disc Access

Since the description of the lumbar intervertebral disc as a potential source of spine pain by Mixter and Barr in 1934, the intervertebral disc has been the focus of spine-based care. Unfortunately, radiographic imaging has limitations in the clinical evaluation of the spine. Imaging studies such as plain radiography, computed tomography (CT), and magnetic resonance imaging can demonstrate anatomic abnormalities but cannot definitively localize the source of spinal pain. Lumbar provocation discography is a method for identifying one or more intervertebral discs as a pain generator. Most importantly, data collection includes pain provocation (i.e., none, discordant, or concordant) correlated with the patient's clinical scenario. Furthermore, it includes manometry (pressure at pain provocation), contrast volumes, and disc architecture (nucleogram and post-discography CT).

Over the last 60 years, the usefulness of discography has been debated, but the discussion of this ongoing controversy is beyond the scope of this chapter. Therefore, the focus of these chapters is on the technical performance of the procedure.

When performing discography, the target of the final needle tip is the nucleus pulposus in the geometric center of the disc. These chapters will describe and demonstrate an extradural "oblique" technique to efficiently and safely access the disc. The transdural approach is neither recommended nor demonstrated.

We recommend using an introducer needle technique using either an 18-G introducer with 22-G needle or a 20-G introducer with 25-G needle, although a single-needle technique may be used. The needle tip can be modified as described in Chapters 2 and 17B to optimize needle navigation. Unless there are prohibiting factors, needle entry contralateral to the more painful side is preferable to prevent the misinterpretation of procedural pain as reproduction of the patient's typical pain. Multiplanar imaging will be used to safely and efficiently advance the needle tip into its final position.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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7. Carragee EJ, Chen Y, Tanner CM, Truong T, Lau E, Brito JL. Provocative discography in patients after limited lumbar discectomy: a controlled, randomized study of pain response in symptomatic and asymptomatic subjects. *Spine*. 2000;25(23):3065–3071.
8. Carragee DJ, Don AS, Hurwitz EL, Cuellar JM, Carrino JA, Herzog R. 2009 ISSLS Prize Winner: Does discography cause accelerated progression of degeneration changes in the lumbar disc: a ten-year matched cohort study. *Spine*. 2009;34(21):2338–2345.
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CHAPTER 17A

Lumbar Provocation Discography/Disc Access: Standard Fluoroscopic Techniques

Thomas S. Lee, Luis Baez-Cabrera, William A. Ante, and Michael B. Furman

This chapter describes and demonstrates strategies to utilize anteroposterior (AP) and lateral imaging to optimally drive the needle tip to a lumbar disc's central target. It also includes additional information about discographic image interpretation.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

Confirm the level (with the AP view).

- **Tilt the fluoroscope's image intensifier** cephalad or caudad.
- Line up the superior end plate (SEP) of the caudad vertebral body for the individual level being targeted.
- Optional: Place an abdominal pillow lateralized ipsilateral to the needle entry side to reduce lumbar lordosis and to obtain 5 to 10 degrees of additional obliquity.
- Lay patients with protuberant abdomens slightly oblique, so the needle entry side is elevated; their abdomen may otherwise theoretically push the retroperitoneum into the needle's trajectory.

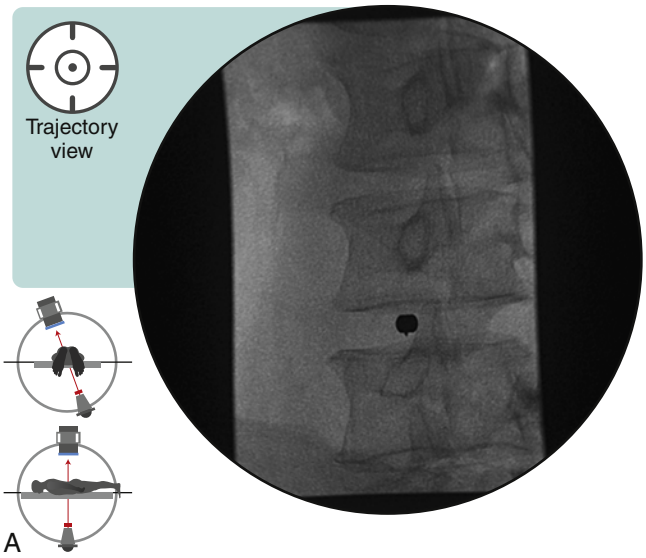
Oblique the fluoroscope's image intensifier ipsilateral to the needle entry (Fig. 17A.1).

- Position the fluoroscope such that the superior articular process (SAP) is bisecting or nearly bisecting the SEP.
- The target needle destination is the part of the disc immediately anterior to the junction of the inferior aspect of the SAP and SEP.
- Adjust the degree of angulation for each individual intervertebral disc level.

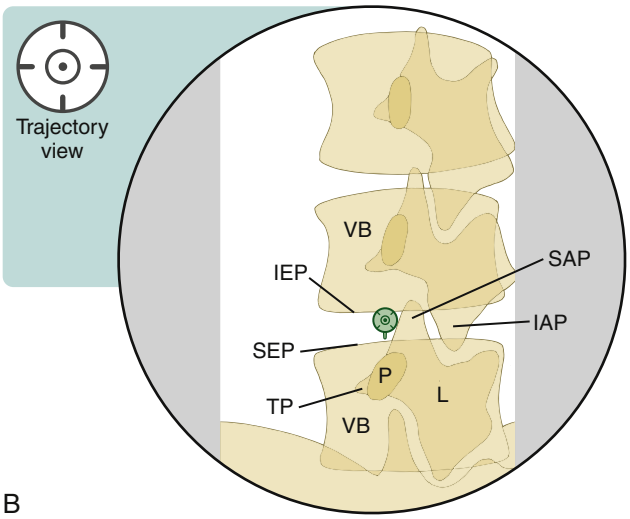
Place the needle parallel to the fluoroscopic beam.

Notes on Positioning in the Trajectory View

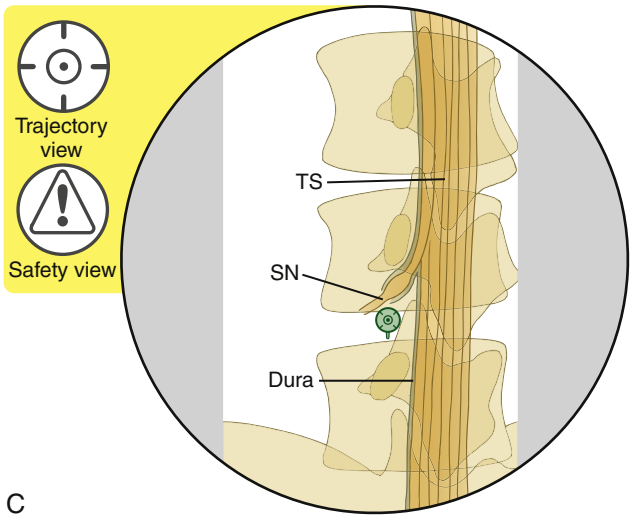
- For each level, the setup is individualized by changing the oblique angulation and tilting of the image intensifier.
- For time efficiency and to minimize radiation, do not transition between the AP and lateral views or vice versa until all intended needle levels have been placed (trajectory view). Then, rotate to the alternate view. If needed, perform minor adjustments to all needles before re-checking.



A



B



C

Trajectory View Safety Considerations

- Avoid the exiting spinal nerve. Superior or lateral migration of the needle tip can contact the spinal nerve.
- Maintain the needle tip immediately anterolateral to the inferior base of the SAP and rostral to the SEP, i.e., "low in the hole" at the SAP/SEP junction.
- Avoid the dura. While advancing the needle toward the disc, do not drive too far medial until entering the disc. A medial straying needle can enter the dura and thecal sac (TS).

Fig. 17A.1. A, Fluoroscopic image of a trajectory view with the needle in position. **B,** Radiopaque structures. The SAP bisects the SEP. **C,** Radiolucent structures.

Optimal Needle Position in Multiplanar Imaging

Optimal Needle Positioning in the Anteroposterior View (Fig. 17A.2)

The "true" AP visualization of each individual intervertebral disc is imperative (see Chapter 3 for discussion on "true" AP). The geometric center of the disc is in line with the position of the spinous process of the superior vertebral body.

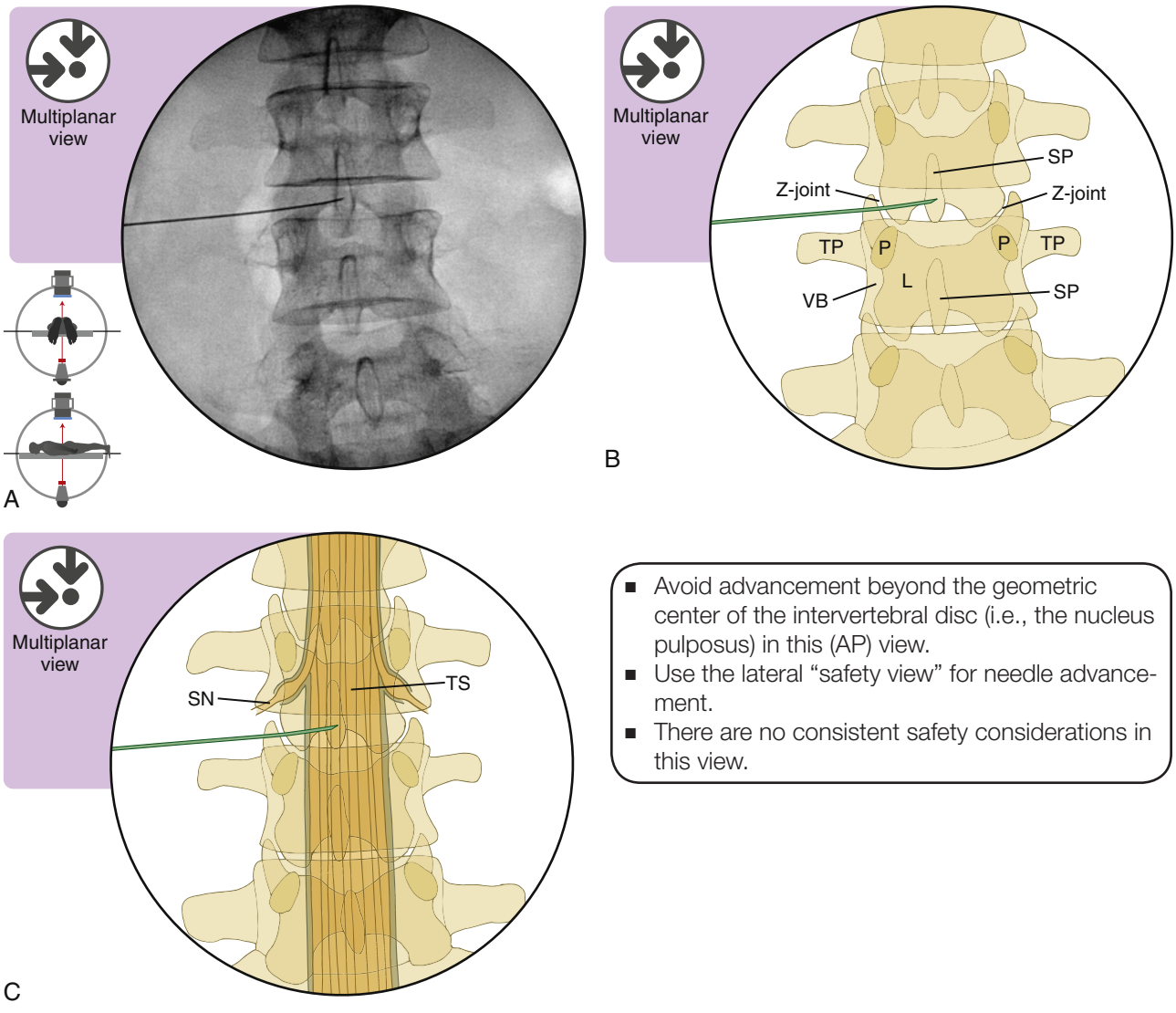


Fig. 17A .2. A, Fluoroscopic anteroposterior view with the ideal needle position. **B,** Radiopaque structures. **C,** Radiolucent structures.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (Fig. 17A.3)

Position the C-arm to obtain a "true" lateral view of each intervertebral disc for the advancement of the needle. This view is the safety view.

Notes on Optimal Needle Position

- The target needle position is within the geometric center of the intervertebral disc (i.e., the nucleus pulposus).
- The C-arm may need to be transitioned from the lateral and AP views multiple times to safely and successfully navigate the needle.
- See Table 17A.1: Using the Anteroposterior and Lateral Fluoroscopic Views to Triangulate/Calculate Axial Needle Tip Position, With Associated Corrections and Clinical Pearls

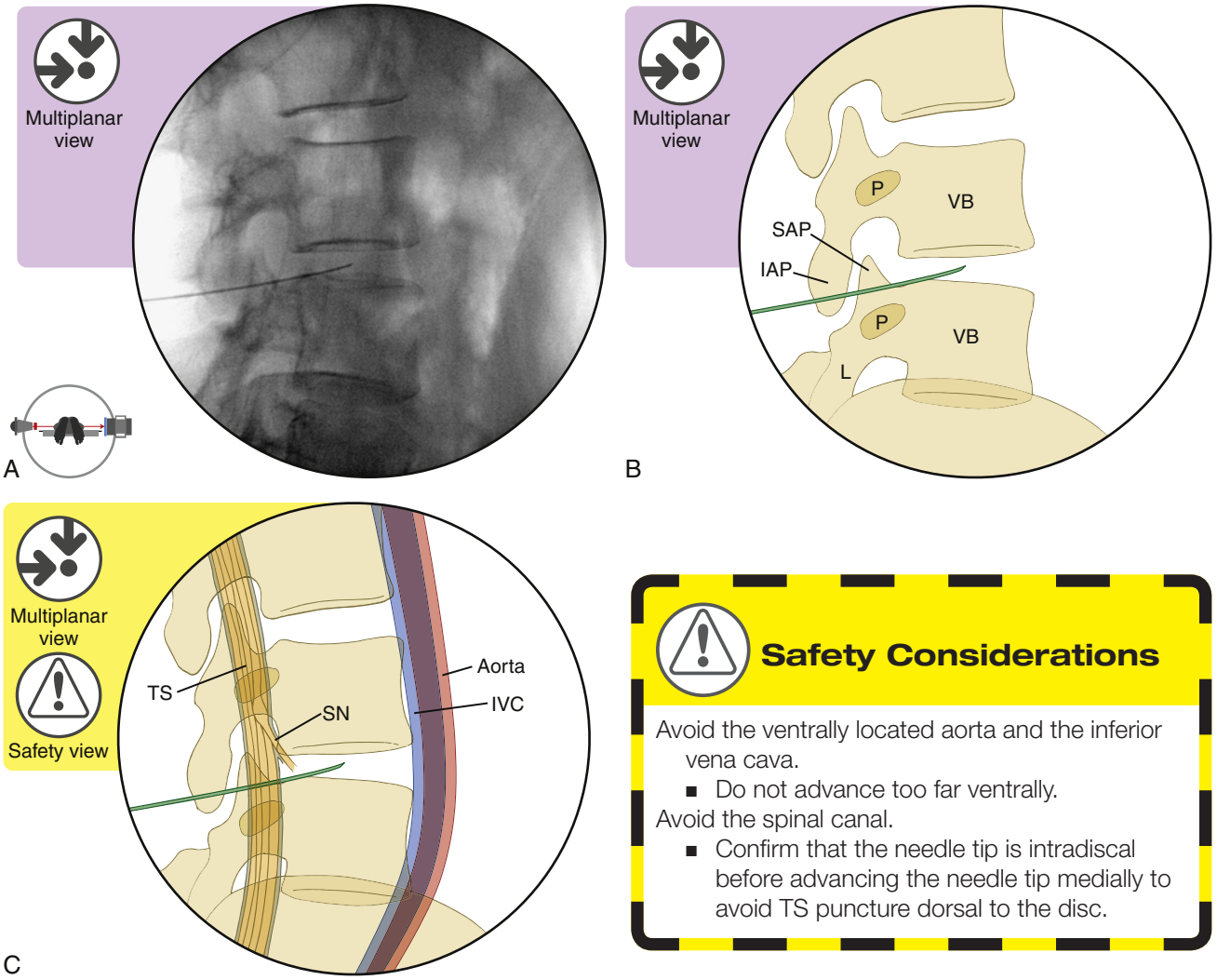


Fig. 17A.3. **A,** Fluoroscopic lateral view with the ideal needle position. **B,** Radiopaque structures. **C,** Radiolucent structures.

Optimal Contrast Images (Figs. 17A.4 to 17A.8)

Optimal Image

- Nucleogram patterns (below) can often be used to anticipate post-discography computed tomography (CT) axial imaging (see Figs. 17A.10 and 17A.11).
- Ideal flow should begin within the nucleus pulposus, and there should be no immediate disappearance of contrast.
- For normal, non-degenerated discs, the flow pattern should appear to have a "cotton ball" or "lobular" form on the nucleogram.
- For degenerated discs, the flow pattern should appear "irregular," "fissured," or "ruptured" on the nucleogram.

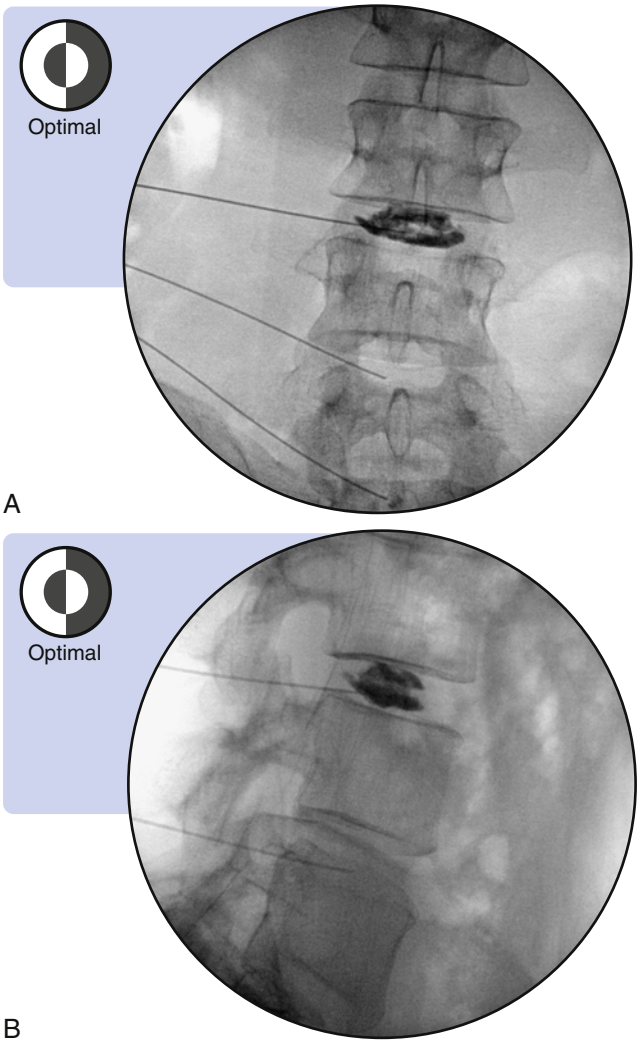


Fig. 17A.4. A, Anteroposterior fluoroscopic image of lumbar discography at L3-L4 with 1.5 cc of contrast with a lobular nucleogram. **B,** Lateral fluoroscopic image of lumbar discography at L3-L4 with 1.5 cc of contrast with a lobular nucleogram.

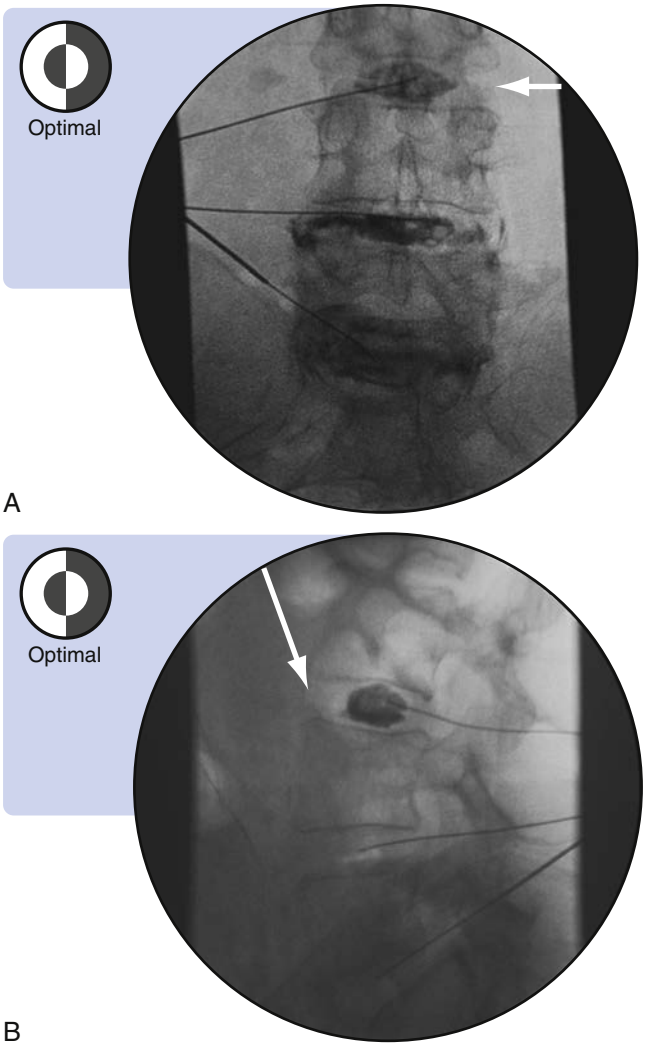


Fig. 17A.5. A, Anteroposterior fluoroscopic image of lumbar discography at L3-L4 with 1.2 cc of contrast with a cotton ball nucleogram (level indicated with white arrow). **B,** Lateral fluoroscopic image of lumbar discography at L3-L4 with 1.2 cc of contrast with a cotton ball nucleogram.

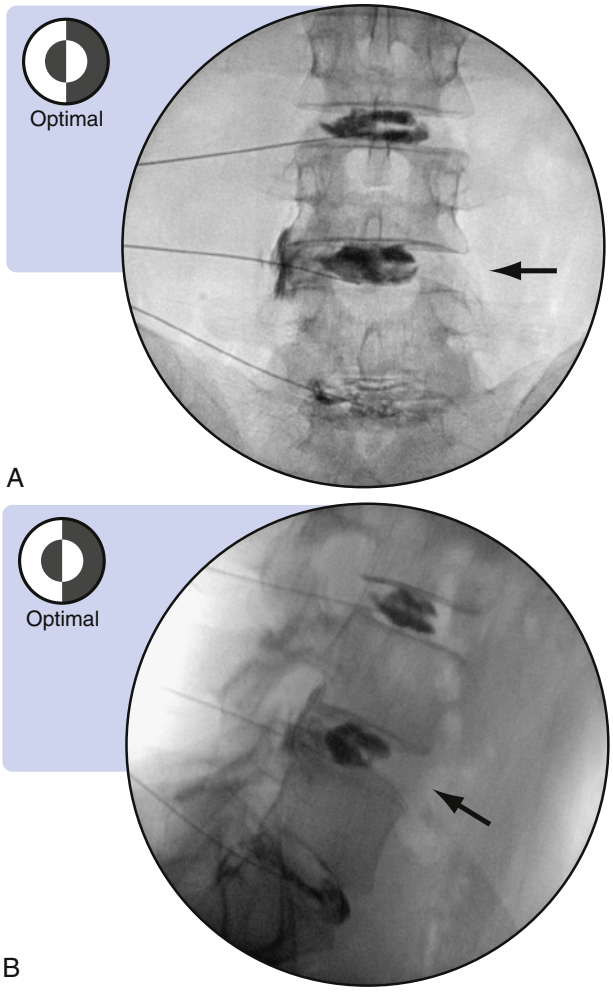


Fig. 17A.6. A, Anteroposterior fluoroscopic image of lumbar discography at L4-L5 with 2.2 cc of contrast with a fissured nucleogram (level indicated with black arrow). **B,** Lateral fluoroscopic image of lumbar discography at L4-L5 with 2.2 cc of contrast with a fissured nucleogram with contrast extending to the posterior annulus.

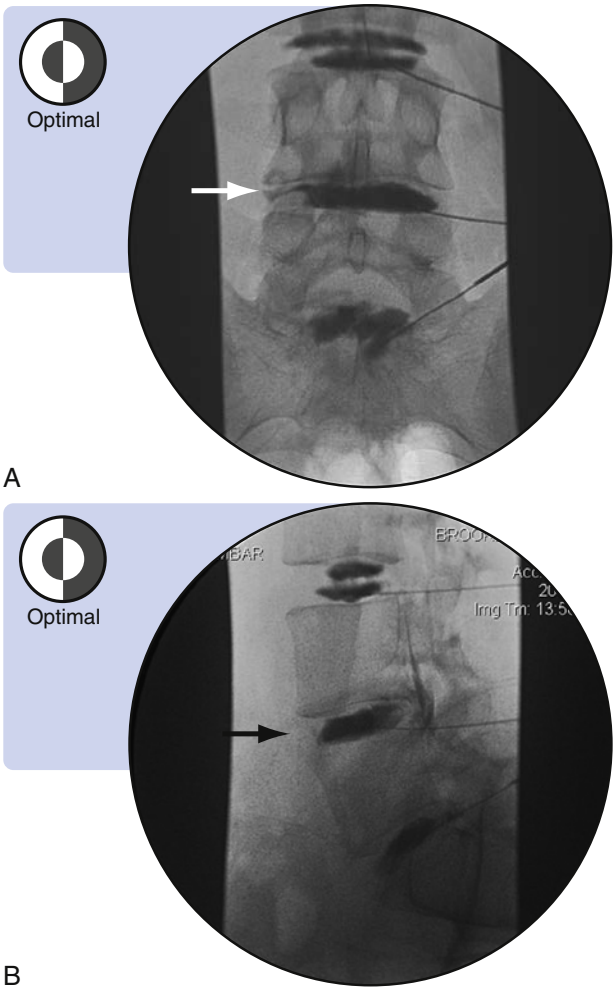


Fig. 17A.7. A, Anteroposterior fluoroscopic image of lumbar discography at L4-L5 with 2.8 cc of contrast with a ruptured nucleogram (level indicated with white arrow). **B,** Lateral fluoroscopic image of lumbar discography at L4-L5 with a ruptured nucleogram and contrast visualized in the ventral epidural space (level indicated with black arrow).

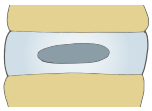
Discogram type		Stage of disc degeneration
1. Cotton ball		No sign of degeneration. Soft white amorphous nucleus
2. Lobular		Mature disc with nucleus starting to coalesce into fibrous lumps
3. Irregular		Degenerated disc with fissures and clefts in nucleus and inner annulus
4. Fissured		Degenerated disc with radial fissure leading to the outer edge of the annulus
5. Ruptured		Disc has a complete radial fissure that allows injected fluid to escape. Can be in any state of degeneration.

Fig. 17A.8. Illustrated examples of Adams nucleogram classification. Adapted from Adams MA, Dolan P, Hutton WC. The stages of disc degeneration as revealed by discograms. *J Bone Joint Surg Br*. 1986;68:36-41.

Suboptimal Images (Figs. 17A.9 and 17.10)

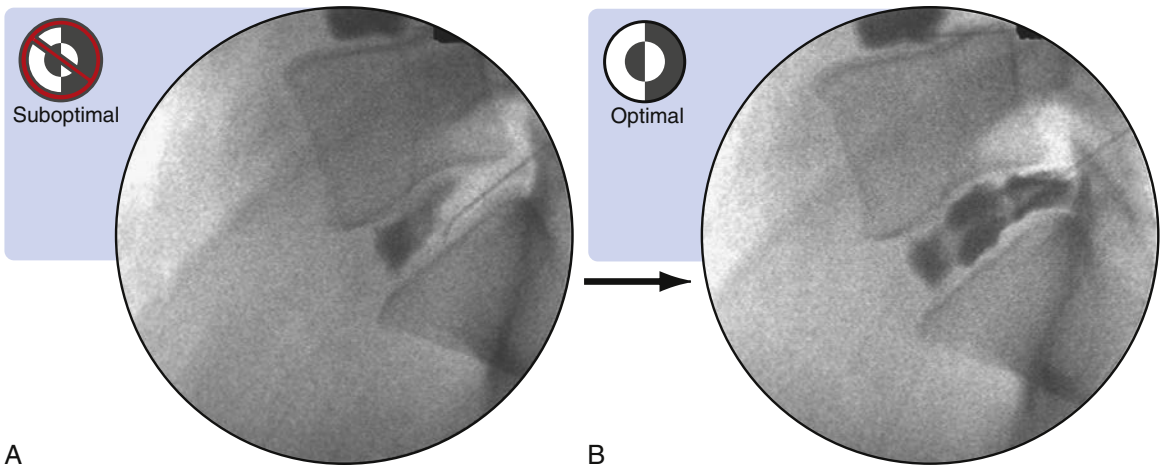


Fig. 17A.9. A, Lateral view demonstrating flow limited to the annulus fibrosis, with an absence of flow into the nucleus pulposus. The needle should be repositioned so that the flow is within the nucleus pulposus. **B,** After the repositioning of the needle. This lateral view demonstrates optimal flow.

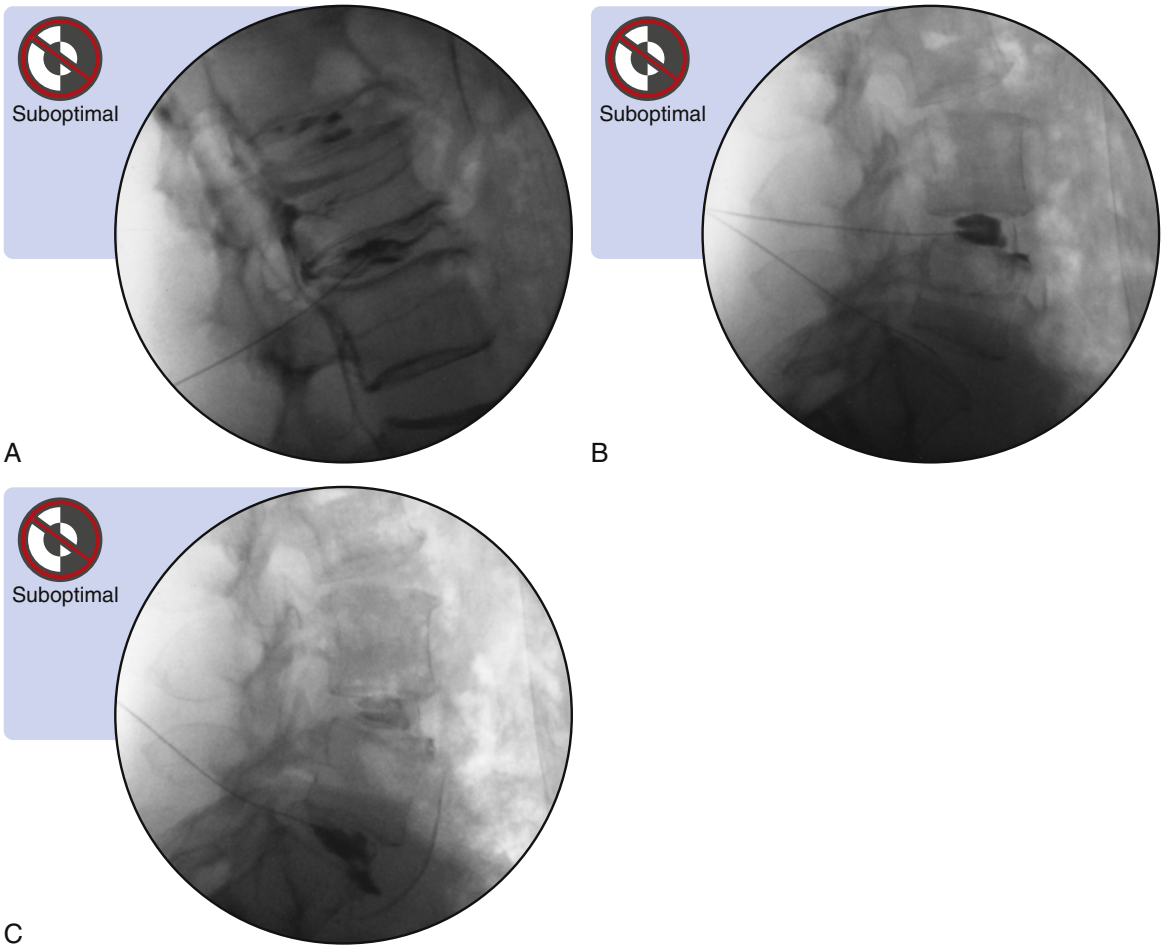
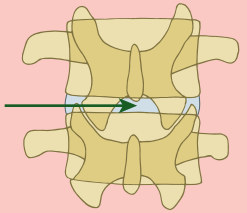
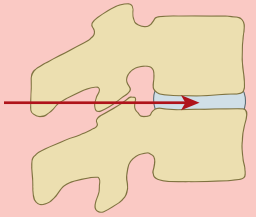
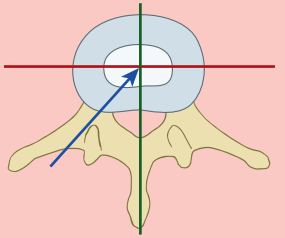
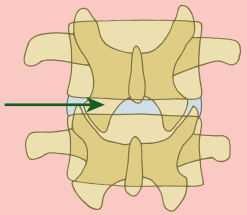
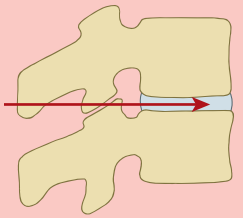
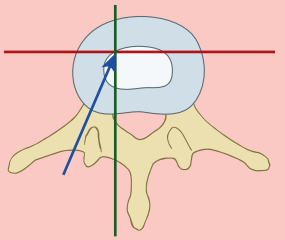
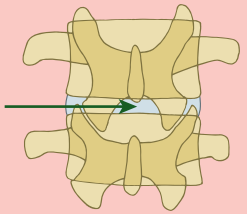
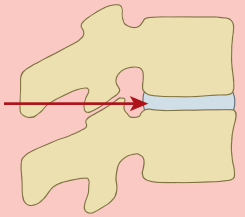
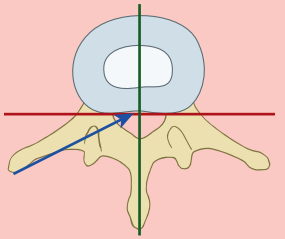
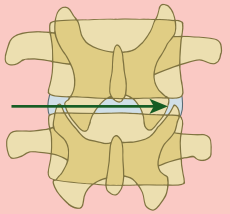
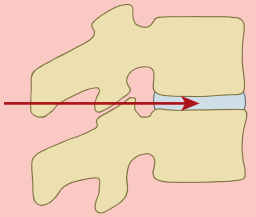
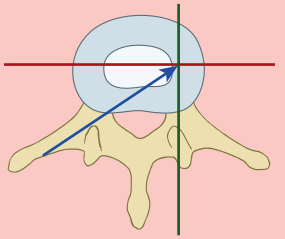


Fig. 17A.10. Intravascular disc injections can occur in 14.3% of injections. **A,** Contrast injection into the L2-L3 disc revealing extensive intravascular uptake in the epidural venous plexus. **B,** Contrast injection into the L4-L5 disc indicating normal nucleogram and some intravenous uptake. **C,** Contrast injection in the L5-S1 disc of the same patient in B with intravenous uptake seen in the inferior vena cava. Note the almost complete dissipation of intravenous contrast from the L4-L5 level. (From Goodman BS, Lincoln CE, Deshpande KK, Poczatek RB, Lander PH, DeVivo MJ. Incidence of intravascular uptake during fluoroscopically guided lumbar disc injections, a prospective observational study. *Pain Physician.* 2005;3:263-266.)

Table 17A.1 Using AP and Lateral Fluoroscopic Views to Triangulate/Calculate Axial Needle Tip Position, With Associated Corrections and Clinical Pearls

	AP View Arrow tip location determines Right/Left position (Green line)	**Lateral View Arrow tip location determines Anterior/ Posterior position (Red line)**	**Calculated Axial Needle Tip in a Prone Patient Intersection of green and red lines determines needle tip position (Blue arrow tip)**	**Correction/Clinical Pearls**
Orientation	Left Right	Posterior Ventral	Left Right	
Optimal approach				Optimal position; no adjustment needed Needle tip is optimally located at the center of the disc (nucleus pulposus).
Needle too ventral, not medial enough. Most typical especially at L5-S1 because of the iliac crest				Needle suboptimally approaching the anterior annulus. Needle needs to be less ventral in the lateral view. If the needle tip is too far ventral, it can miss the nucleus pulposis and instead be in the annulus Initial setup was not oblique enough. Check multiplanar imaging frequently. Other options (see Chapter 17B): ■ Overtilt ■ Curve needle tip Check multiplanar imaging frequently. This is the most common pitfall
Needle too medial and not ventral enough				Needle is noted to traverse the spinal canal. Needle needs to be less medial. Initial setup was too oblique. Check multiplanar imaging frequently. Confirm that the needle tip is intradiscal before advancing it medially to avoid the thecal sac puncture dorsal to the disc.
Needle is far too medial				Needle is noted in the far lateral annulus. Aim more ventrally. Initial setup was too oblique. Check multiplanar imaging frequently.

AP, anteroposterior.

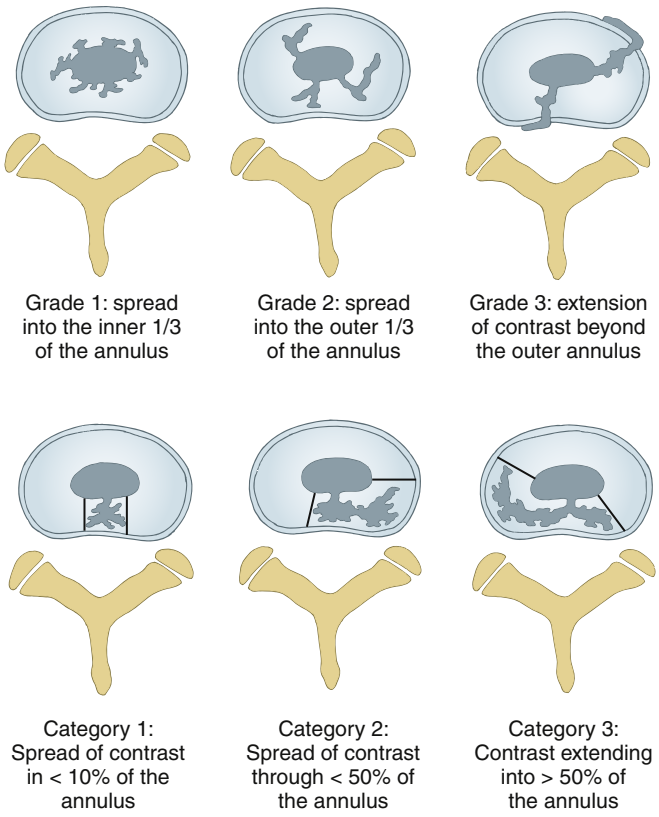


Fig. 17A.11. Original Dallas scale. The "grade" describes radial contrast extension, and "category" describes annulus circumferential contrast extent.

Table 17A.2 (Original) Dallas Discogram Scale

Annular Degeneration	Annular Disruption
0: No change	0: None
1: Local, less than 10%	1: Into the inner annulus
2: Partial, less than 50%	2: Into the outer annulus
3: Total, more than 50%	3: Beyond the outer annulus

ADDITIONAL INFORMATION

When performing discography, several data points are to be considered.

Pain response

- Intensity—target: ≥6/10 numeric rating scale (NRS)
- Concordance with typical pain location
  - Discordant (P±): An equivocal response; vague, uncharacteristic, or discordant pain, both by nature and location
  - Similar (P+): Definite convincing pain provocation that is familiar to the patient but that only reproduces part of the symptom complex
  - Exact (P++): Exact pain reproduction that is concordant with the symptom complex
  - Pain free: P0

Nucleography: Adams Classification (Fig. 17A.8)

- Cotton ball
- Lobular
- Irregular
- Fissured
- Ruptured

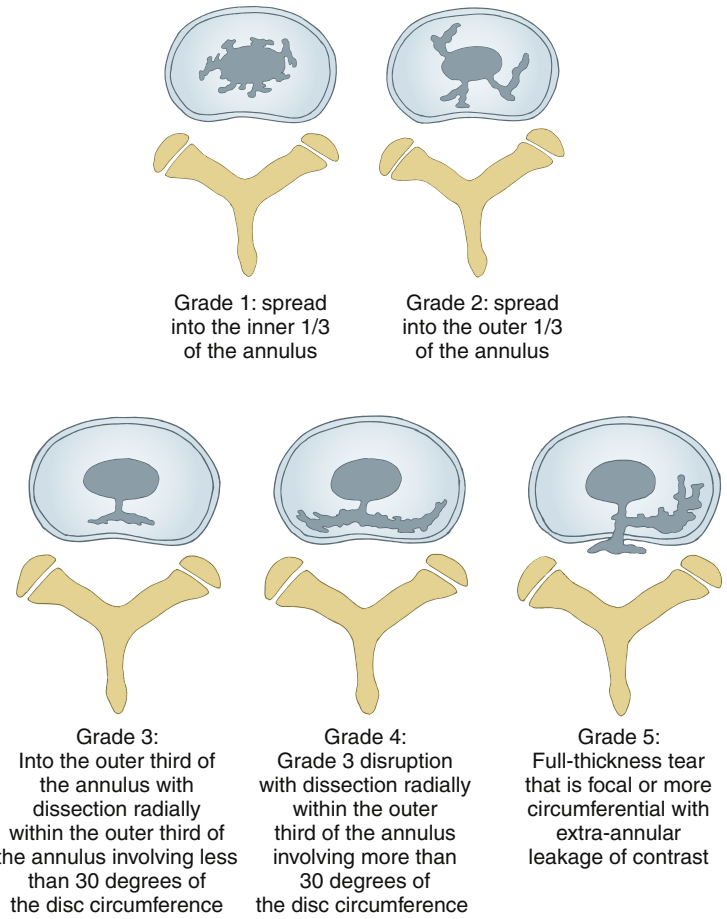

Grade 1: spread into the inner 1/3 of the annulus
Grade 2: spread into the outer 1/3 of the annulus
Grade 3: Into the outer third of the annulus with dissection radially within the outer third of the annulus involving less than 30 degrees of the disc circumference
Grade 4: Grade 3 disruption with dissection radially within the outer third of the annulus involving more than 30 degrees of the disc circumference
Grade 5: Full-thickness tear that is focal or more circumferential with extra-annular leakage of contrast

Fig. 17A.12. Modified Dallas scale. Same as Dallas scale except for the modification of grade 3 and two additional grading levels for annular disruption. This modified Dallas grading system is the typical one currently used. It includes grades 1 and 2 from the original Dallas scale. The newer grades 3 and 4 combine both radial and annular circumferential contrast extent, and grade 5 describes annular leakage.

Antibiotics

- Periprocedure antibiotics are advised to minimize the chance of infection. Listed below are both intravenous and intradiscal options. However, intradiscal antibiotics are controversial and not utilized by the authors.
- Cefazolin, 1 to 2 g intravenously, 1 to 10 mg/ml intradiscally, or both
- If the patient is allergic to penicillin or cephalosporins:
  - Clindamycin, 600 mg intravenously, 7.5 mg/ml intradiscally, or both
  - Vancomycin, 1 g intravenously to patients with methicillin-resistant *Staphylococcus aureus*
- Some clinicians may take a portion of the total intravenous antibiotic and combine it with the contrast to provide antibiotics via intravenous and intradiscal administration
- Recommend starting antibiotics 30 minutes before the start of the case (unless using vancomycin, which should be started 60 minutes before the start of the case)
- If intradiscal placement is in question, needle tip verification with the use of a contrast without antibiotic needs to be considered

Manometry

Manometry should be used to provide standardized pressurization of the intervertebral disc.

- Pressure (Table 17A.2)
  - Opening (A): pressure when contrast is first observed in the disc
  - Maximum or level at pain provocation (B)
  - Delta: pressure difference between B and A (i.e., B – A)
  - Maximum volume is 3.0 cc
  - In Table 17A.3, the disc classification is the currently accepted model. However, there is ongoing discussion to improve the validity and to minimize false-positive results.

Table 17A.3 Discographic Diagnostic Categories

Disc Classification	Delta Pressure at Pain Provocation
Low pressure	Less than or equal to 15 psi
High pressure	Between 16 and 50 psi
Indeterminate	Between 51 and 90 psi
Normal	No pain; greater than 90 psi

- Speed of injection
  - Up to 0.2 cc per second
  - With a 25-G needle, <0.1 cc per second
  - Currently, the issue of manual pressure-controlled injection versus automated pressure-controlled injection is ongoing.
  - Monitor pressure reading and contrast flow continuously or at least approximately every 0.5 cc.
- Control level
  - One non-painful level, P0, is recommended to confirm the internal validity of the test.
- Reproducibility
  - At suspected painful intervertebral disc levels, one should be able to reproduce the results during repressurization
- Utility of post-discography computed tomography
- CT is not required after every discography.
- It is recommended, if needed, for accurate data interpretation (e.g., if the nucleogram at a given level appears lobular, but there is an NRS 6/10 and P++ pain response).
- If ordered, ensure that axial images are parallel to the intervertebral discs being studied.
- It is recommended to be completed within 2 hours of discography completion.
- Use the Dallas (Table 17A.3 and Fig. 17A.10) or modified Dallas (Fig. 17A.11) discogram scale for interpretation.

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15. Derby R, Lee SH, Kim BJ, Chen Y, Aprill C, Bogduk N. Pressure-controlled lumbar discography in volunteers without low back symptoms. *Pain Med*. 2005;6(3):213–221.
16. Derby R, Kine G, Schwarzer A, Howard M. The relationship between intradiscal pressure and pain provocation during discography. *J Bone Joint Surg*. 1995;19:59–60.
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Suggested Readings

Adams MA, Dolan P, Hutton WC. The stages of disc degeneration as revealed by discograms. *J Bone Joint Surg Br*. 1986;68(1):36–41.

Goodman BS, Lincoln CE, Deshpande KK, Poczatek RB, Lander PH, DeVivo MJ. Incidence of intravascular uptake during fluoroscopically guided lumbar disc injections: a prospective observational study. *Pain Physician*. 2005;8(3):263–266.

L5-S1 Disc Access

CHAPTER 17B

Thomas S. Lee, William A. Ante, and Michael B. Furman

This chapter describes strategies to enter the L5-S1 disc, which requires a modified technique, and delineates the "tricks" to approach the L5-S1 disc when the posterior iliac crest makes access more challenging. Initially, we present a direct trajectory that is similar to that described in Chapter 17A. For patients with high iliac crests or other technical limitations, additional options are presented. The "tricks" described here optimize the L5-S1 disc access, including the "over-tilt" and curved needle techniques. If only one "trick" is to be used, the "over-tilt" will often be sufficient.

We will also demonstrate the fluoroscopic axial view; this is an imaging technique that is unique to the L5-S1 disc because of the lumbosacral lordosis.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

DIRECT TRAJECTORY TECHNIQUE

This technique is used if the iliac crest does not obscure access to the L5-S1 disc space. The technique will result in an initial trajectory that is identical to that seen with standard disc access (see Chapter 17A), as long as the iliac crest can be cleared.

Trajectory View

Confirm the level (with the anteroposterior view).
Tilt the fluoroscope's image intensifier cephalad.

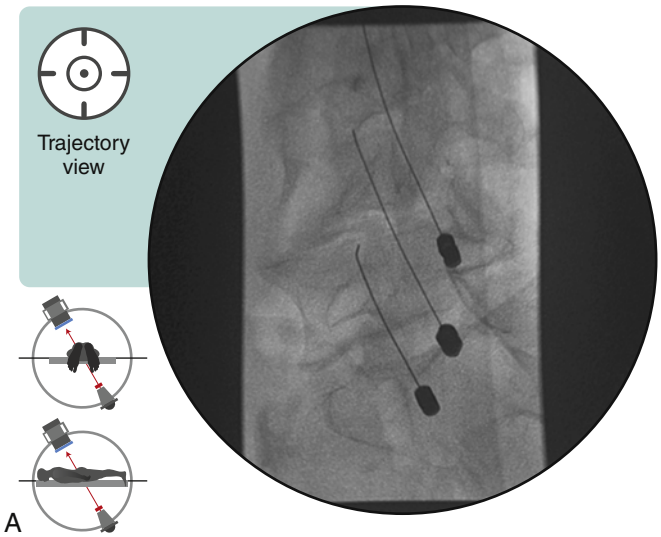
- Optimize visualization of the L5-S1 disc by adjusting the degree of tilt and lining up the S1 superior end plate (SEP), L5 inferior end plate (IEP), or both.
- Typically, greater cephalad tilt is required compared with the other disc levels to position the posterior iliac crest away from the point of disc entry. Therefore, preferentially **lining up the S1 SEP (instead of the L5 IEP) will improve the likelihood of clearing the iliac crest as a result of the S1 SEP's more cephalad orientation.**
- Optional: Place an abdominal pillow lateralized ipsilateral to the needle entry side to reduce lumbar lordosis and to obtain 5 to 10 degrees of additional obliquity.
- Lay patients with protuberant abdomens slightly oblique, so the needle entry side is elevated; their abdomen may otherwise theoretically push the retroperitoneum into the needle's trajectory.

Oblique the fluoroscope's image intensifier ipsilateral to needle insertion (Fig. 17B.1).

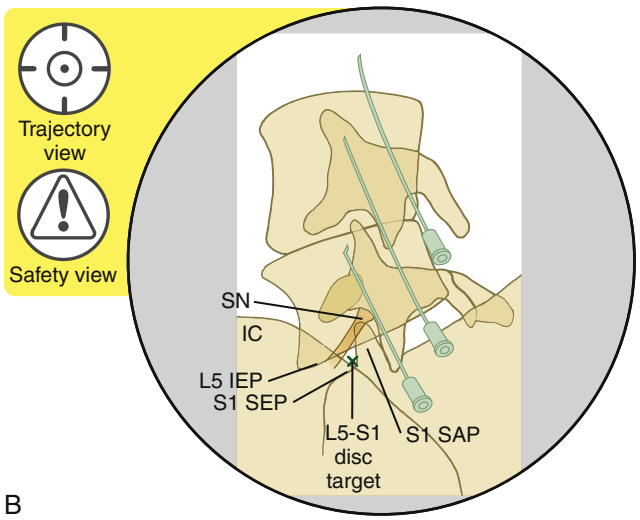
- Attempt to position the fluoroscope such that the superior tip of the S1 superior articular process (SAP) is bisecting or nearly bisecting the diameter of the S1 SEP.
- The target needle destination is immediately anterior to the junction of the SAP and the S1 SEP.
- If you cannot clear the iliac crest with this technique, use one of the alternate techniques described later in this chapter (i.e., the "over-tilt" or curved needle technique).

Notes on Positioning in the Trajectory View

- The posterior iliac crest often obstructs the visualization of the optimal trajectory of the target needle entry site, despite other trajectory view optimization techniques.
- To visualize the entry site, less ipsilateral oblique of the intensifier may be required; this may complicate the positioning of the SAP bisecting the diameter of the SEP.
- Solving this visualization challenge while getting a reasonable trajectory may require one or both of the "tricks" described in this chapter; however, often the "over-tilt" will be all that is needed.



A



B

Trajectory View Safety Considerations

- Avoid the L5 spinal nerve (SN). Superior or lateral migration of the needle tip can contact the SN.
- Remain immediately anterior to the junction of the S1 SEP and the inferior base of the S1 SAP, i.e., "low in the hole."
- Avoid the dura. While advancing the needle toward the disc, do not drive too far medial until entering the disc. A medial straying needle can enter the dura.

Fig. 17B.1. A, Fluoroscopic image of the trajectory view of the L5-S1 disc. **B,** Radiopaque and radiolucent structures. The three needles shown in the picture are already placed in the three cephalic discs. The green "X" identifies the trajectory. If the iliac crest does not block the access to the L5-S1 disc then no other "trick" is necessary. Simply access the disc as described in Chapter 17.

THE "OVER-TILT"

The "over-tilt cheat" is a technique that utilizes an initial cephalad tilt trajectory that is not entirely parallel to the L5-S1 disc to pass the needle above the iliac crest.

- Visualize the midpoint of the target L5-S1 disc with the appropriate ipsilateral oblique rotation. The S1 SAP should bisect the diameter of the S1 SEP, but the iliac crest will still overlap the target point (Fig. 17B.2, *A* and *B*).
- "Over-tilt" the image intensifier cephalad until the iliac crest appears inferolateral to the disc and no longer overlaps the optimal target, which has already been described. This will typically end up being tilted too cephalad ("over-tilted"), with the end plates no longer parallel to the fluoroscopic beam (Fig. 17B.2, *C* and *D*).
  - Use an 18- or 20-G spinal needle as an introducer needle.
  - Advance parallel to the fluoroscopic beam to the point immediately lateral to the SAP. The trajectory is no longer parallel to the disc's end plates.
- For the final step of visualization, reduce the cephalad tilt of the image intensifier until the L5 IEP and the S1 SEP are properly lined up. The fluoroscopic beam is now parallel to the disc, but it is no longer parallel to the needle's trajectory (Fig. 17B.2, *E to J*).
  - Place a 22- or 25-G spinal needle through the introducer needle. (For better bevel control, use a slight needle tip bend [see Chapter 2]. Do not bend the needle tip too much if it is a narrow disc space.)
  - After the bent 22- or 25-G needle tip exits the introducer needle's tip and enters the disc, direct the needle tip medially and superiorly to avoid the S1 SEP.
- Anatomy tips
  - With the "over-tilt" technique, the needle trajectory is not initially lateral to the junction of the SAP and the sacral ala (i.e., "low in the hole"). With this approach, the needle tip has a higher potential to be in close proximity to the exiting L5 SN. Slowly advance the tip to minimize the patient's potential pain response and potential neural compromise.
  - Because of the caudad orientation of the needle trajectory just before or immediately after entry into the intervertebral disc, you must direct the needle tip superiorly. Otherwise, the needle tip may not advance because of the contact with the S1 SEP (Fig. 17B.2, *K to N*).

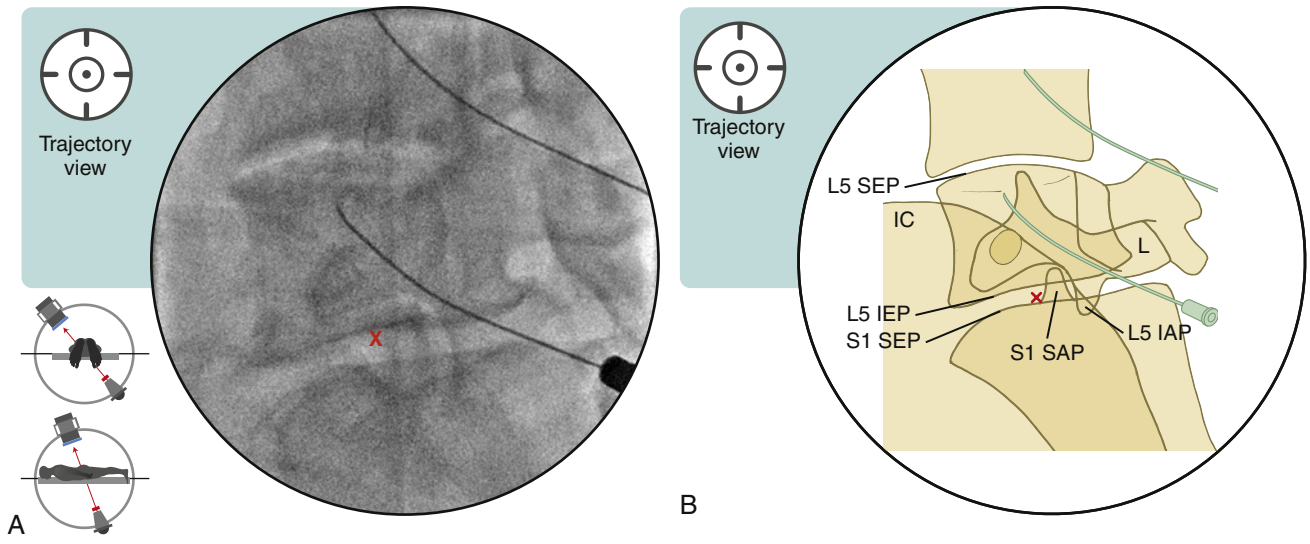


Fig. 17B.2. A, L5-S1 discogram fluoroscopy setup with the S1 SAP bisecting the diameter of the S1 SEP. However, the iliac crest is overlapping the target point *(red "x")*. **B,** Radiopaque structures that correspond to Fig. 17B.2, *A*.

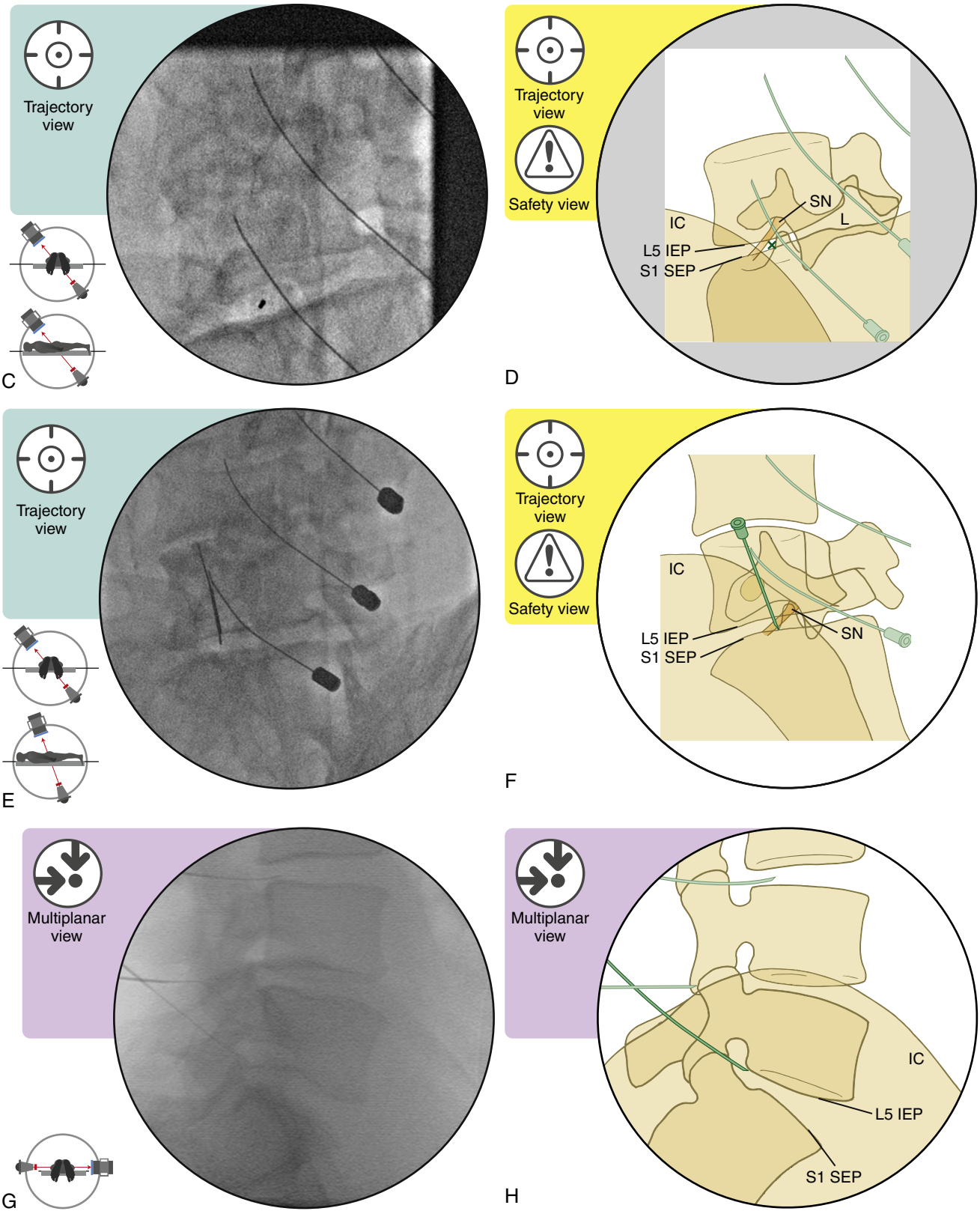
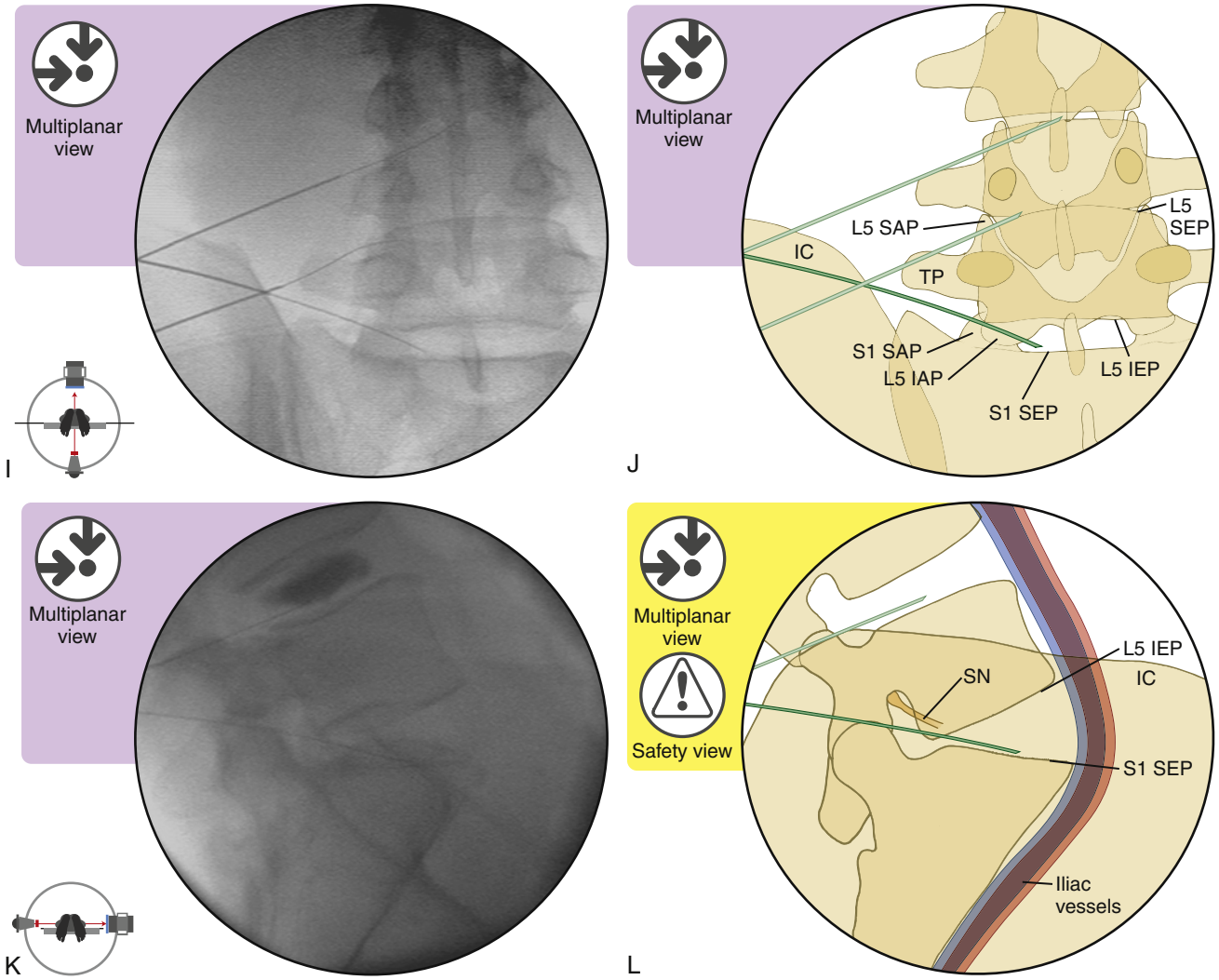


Fig. 17B.2. cont'd C, L5-S1 discogram fluoroscopy setup with the needle placed. The iliac crest is no longer overlapping the target point. Because of the "over-tilted" angle, the disc end plates are no longer lined up. **D,** Radiopaque and radiolucent structures that correspond with Fig. 17B.2, *C*. As always, stay "low in the hole" to avoid hitting the exiting L5 spinal nerve (SN). The small green "x" corresponds to the needle placement for direct L5-S1 entry. **E,** L5-S1 discogram with the introducer needle in place and with the L5 IEP and S1 SEP now lined up. Because the disc end plates are lined up, the needle is not parallel to the beam; hence, this is not a "true" trajectory view. **F,** Radiopaque and radiolucent structures that correspond with part *E* of this figure. L5-S1 discogram with the introducer needle in place and with the L5 IEP and S1 SEP now lined up. Because the disc end plates are lined up, the needle is not parallel to the beam; hence, this is not a "true" trajectory view. **G,** L5-S1 discogram, lateral view, with the needle just entering the intervertebral disc. Note that because the needle trajectory used the "over-tilt," the needle is not parallel to the end plates. **H,** Radiopaque structures that correspond with part *G* of this figure. L5-S1 discogram, lateral view, with the needle just entering the intervertebral disc. Note that because the needle trajectory used the "over-tilt," the needle is not parallel to the end plates.



Safety Considerations

Avoid the common iliac vessels.
- Do not advance too ventrally.

Avoid the spinal canal.
- Do not only advance the needle tip medially if this view shows that the needle is dorsal to the disc.

Fig. 17B.2. cont'd I, L5-S1 discogram, anteroposterior view, with the needle just entering the intervertebral disc. The end plates are lined up, but the needle is entering with the angle used for the "over-tilt" to clear the iliac crest. **J,** Radiopaque structures that correspond with part *I* of this figure. L5-S1 discogram, anteroposterior view, with the needle just entering the intervertebral disc. The end plates are lined up, but the needle is entering with the angle used for the "over-tilt" to clear the iliac crest. **K,** L5-S1 discogram, lateral view, with the needle approaching the geometric center; this is the "final position" of the intervertebral disc. Note that because the "over-tilt" was used, the needle trajectory is not parallel to either end plate and that it is actually aimed toward the S1 SEP. The needle tip will need to be adjusted superiorly. **L,** Radiolucent structures that correspond with part *K* of this figure. L5-S1 discogram, lateral view, with the needle approaching the geometric center; this is the "final position" of the intervertebral disc.

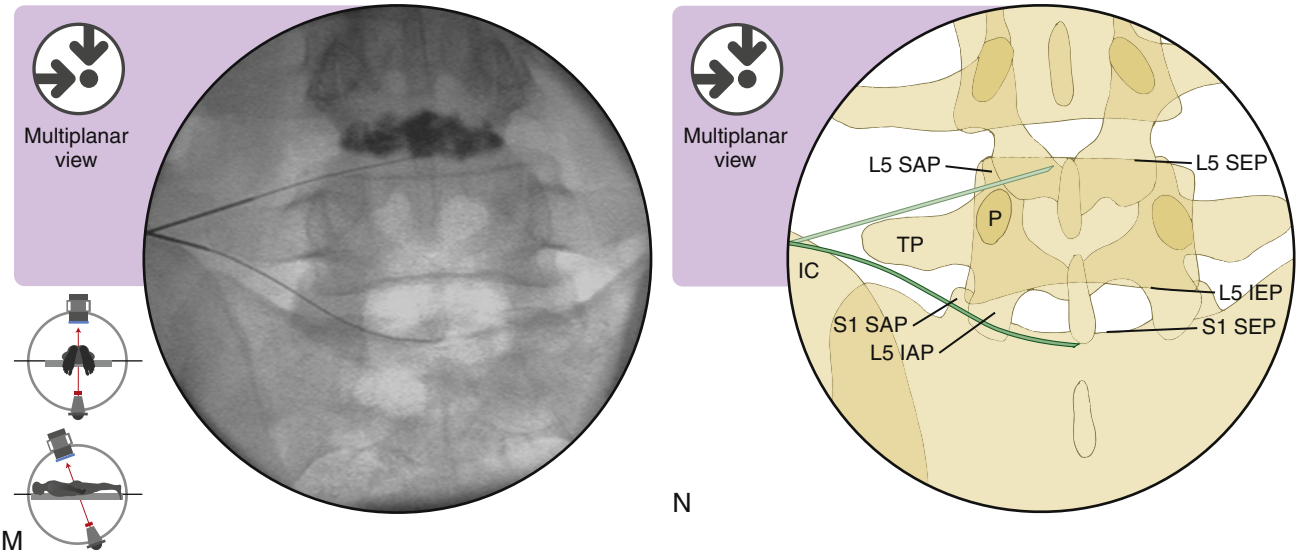


Fig. 17B.2. cont'd M, L5-S1 discogram, anteroposterior view, with the needle in the geometric center; this is the "final position" of the intervertebral disc. **N,** Radiopaque structures that correspond with part *M* of this figure. L5-S1 discogram, anteroposterior view, with the needle in the geometric center; this is the "final position" of the intervertebral disc.

THE "CURVED" NEEDLE TECHNIQUE

The "curved" needle technique is used when the previously described techniques have not been effective. This technique will result in an initial trajectory that is less oblique and more perpendicular to the surface. This will result in intradiscal entry in a more ventral vector, leading to a higher probability of only annular needle placement. The medially directed curve of the needle compensates for the less ideal introducer needle trajectory.

- Manipulate the spinal needle tip to a "curved" geometry (Fig. 17B.3, *A*). It is imperative that the end of the needle has a significant curve. The degree of curve will vary with the circumstances. Fig. 17B.3, *B*, shows a curved 22-G procedure needle put through an 18-G introducer.
- Tilt the image intensifier until the L5 IEP and S1 SEP are lined up.
- Oblique ipsilaterally, with the goal being the S1 SAP bisecting the diameter of the S1 SEP.
  - It is likely that the high-riding iliac crest will block the needle entry to the optimal position.
  - As a result, decrease the oblique angulation until the entry zone is no longer blocked by the iliac crest. This will result in a suboptimal entry that is more perpendicular and less oblique than desired.
- Use an 18- or 20-G spinal needle as an introducer needle with a 22- or 25-G curved intradiscal needle, respectively.
- Advance parallel to the fluoroscopic beam to the point immediately lateral to the S1 SAP (Fig. 17B.4, *A* and *B*).
- Place the curved 22- or 25-G spinal needle through the introducer needle, with the goal of driving it medially into the disc as soon as it exits the introducer. Thus, the introducer and needle's notches should be 180 degrees opposite, with the introducer's bevel facing medially and the needle's curve and tip facing medially (Fig. 17B.3, *C*).
- After the curved needle exits the introducer needle's tip, direct the needle tip medially into the disc while "unsheathing" the inner needle by pulling back on the introducer, which will put more medial "memory" spring into the needle. Confirm that the needle tip is barely in the disc before unsheathing it from the introducer (Fig. 17B.3, *D* and *E*).
- Note that it is not uncommon to combine both the "over-tilt" and the "curved" needle techniques when dealing with a high-riding iliac crest.

The remainder of this chapter provides information about needle positioning after unsheathing.

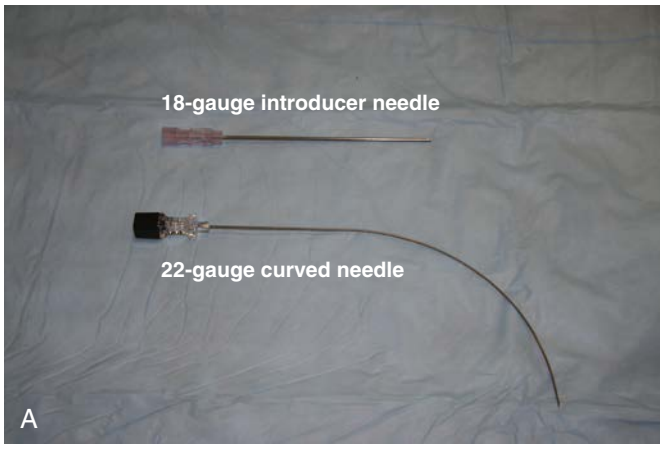


Fig. 17B.3. A, An 18-G introducer needle and a 22-G curved needle shown separately. **B,** L5-S1 discogram curved needle within the introducer needle. The curved needle is placed through the introducer only after the introducer needle is ideally placed. The notches and bevels are opposite each other, as shown in part ***C*** of this figure. **C,** Diagram demonstrating the needle tips of an 18-G introducer needle and an unsheathed exiting 22-G curved needle. The 18-G introducer needle bevel faces medially, and the 22-G needle tip and curve face medially to facilitate a medial trajectory. The notches on the needle hubs are 180 degrees opposite of each other. Note that the notches (shown in black and on top) are 180 degrees apart and that the bevels are 180 degrees apart. **D,** Simulated axial disc view with an ideal needle tip placement facilitated by fully unsheathing and pulling back the 18-G introducer needle. With the unsheathing of the "memory" and "spring" of the needle, the needle is optimized intradiscally. **E,** Simulated axial disc view with suboptimal needle tip placement as a result of incomplete unsheathing.

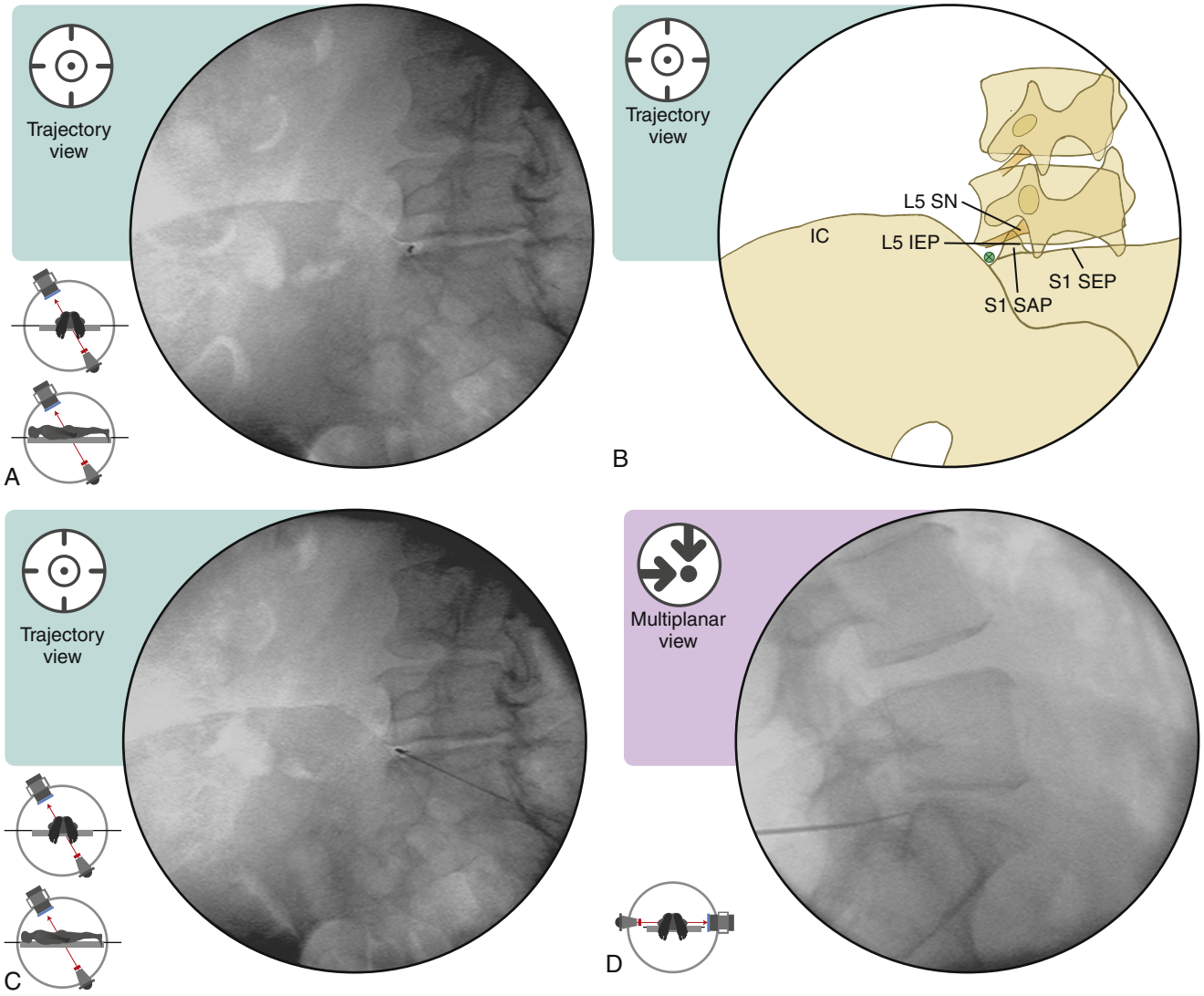


Fig. 17B.4. A, L5-S1 discogram trajectory preparing for the curved needle technique, with only the introducer needle in place. This entry is more perpendicular and with a more ventral vector to access the disc's center than the trajectory without a curved needle. **B,** Radiolucent and radiopaque structures that correspond with part *A* of this figure. L5-S1 discogram trajectory view preparing for the curved needle technique, with only the introducer needle in place. **C,** L5-S1 discogram with a curved needle tip being directed through the introducer and the tip aimed medially toward the disc. **D,** L5-S1 discogram, lateral view, with a curved needle tip at the outer lower edge of the disc before the introducer needle is unsheathed. Ideally, one should wait until the needle tip is barely intradiscal before unsheathing occurs.

Optimal Needle Position in Multiplanar Imaging

These images were obtained after the unsheathing of the introducer when using the "curved" needle approach (see Table 17A.1, Using Anteroposterior and Lateral Views to Interpret Needle Tip Position).

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (Fig. 17B.5)

"True" anteroposterior visualization of the intervertebral disc is imperative. The geometric center of the disc usually is in line with the position of the spinous process of the superior vertebral body.

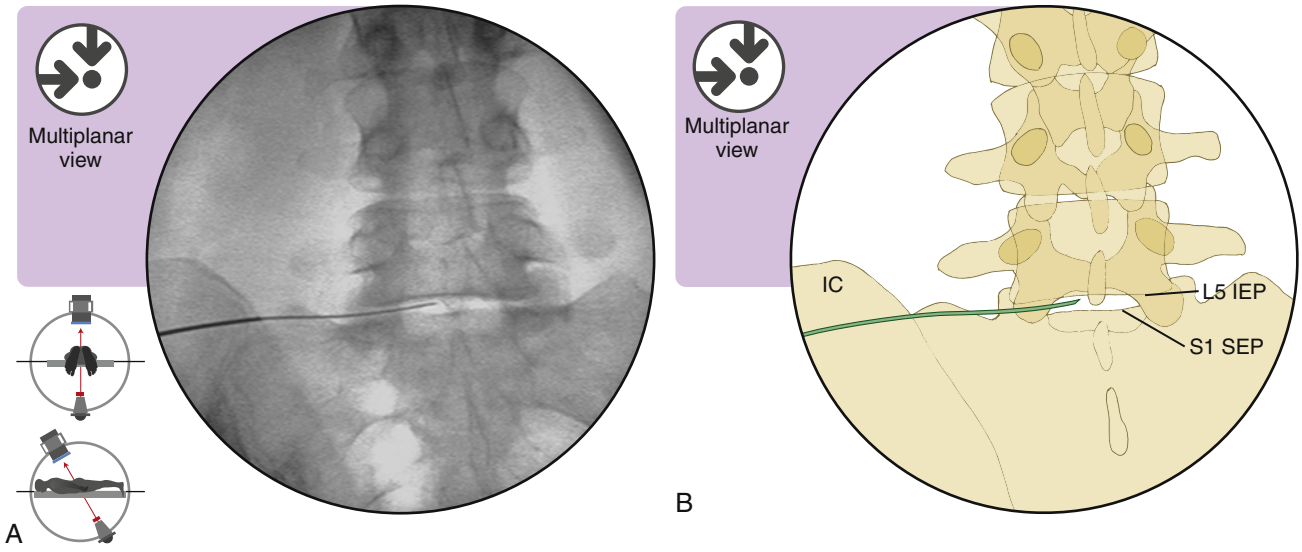


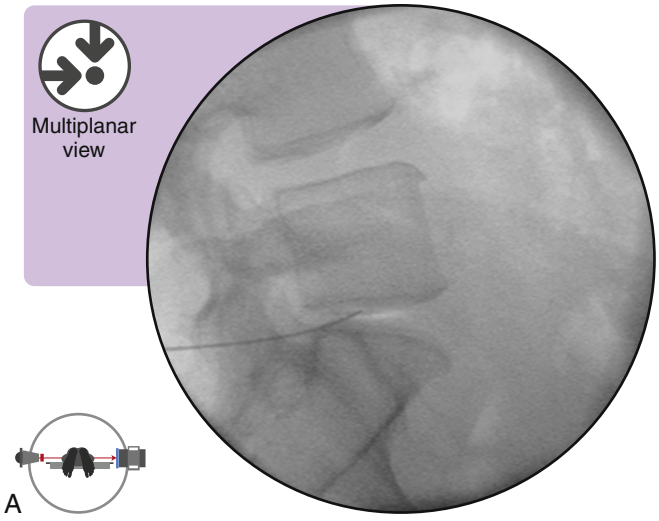
Fig. 17B.5. A, Fluoroscopic anteroposterior view with the ideal needle position, curved two-needle technique. **B,** Radiopaque structures, anteroposterior view.

Notes on Optimal Needle Positioning

- The target needle position is within the geometric center of the intervertebral disc (i.e., the nucleus pulposus).
- The C-arm may need to be transitioned from the lateral and anteroposterior views multiple times to safely and successfully navigate the needle.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (Fig. 17B.6)

Position the C-arm to obtain a "true" lateral view for needle tip advancement. This view is also considered the safety view.



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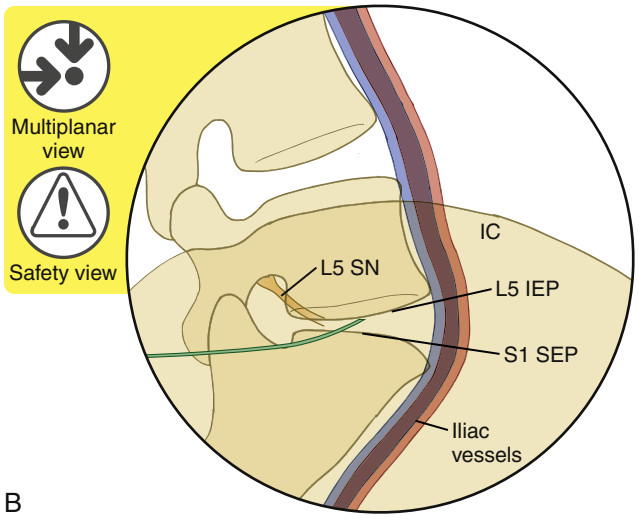

B

Safety Considerations

Avoid the common iliac vessels.
- Do not advance too ventrally.

Avoid the spinal canal.
- Do not only advance the needle tip medially if this view shows that the needle is dorsal to the disc.

Fig. 17B.6. A, Fluoroscopic lateral view with the ideal needle position, curved two-needle technique. **B,** Radiolucent structures, lateral view.

Optimal Images

See Chapter 16 for optimal and suboptimal discography images.

ADDITIONAL FIGURES (Fig. 17B.7)

The fluoroscopic axial (F-axial) view is an axial view of the L5-S1 intervertebral disc that can be visualized during the discography case. This view can be achieved by caudad tilt of the fluoroscope intensifier approximately perpendicular to the "true" anteroposterior visualization of the L5-S1 disc (Fig. 17B.7, *A*). An F-axial view is possible for the L5-S1 disc as a result of the level's unique lordosis. It is typically not possible to get a precise axial view because the image intensifier cannot be sufficiently tilted caudad enough before encountering the patient's buttocks.

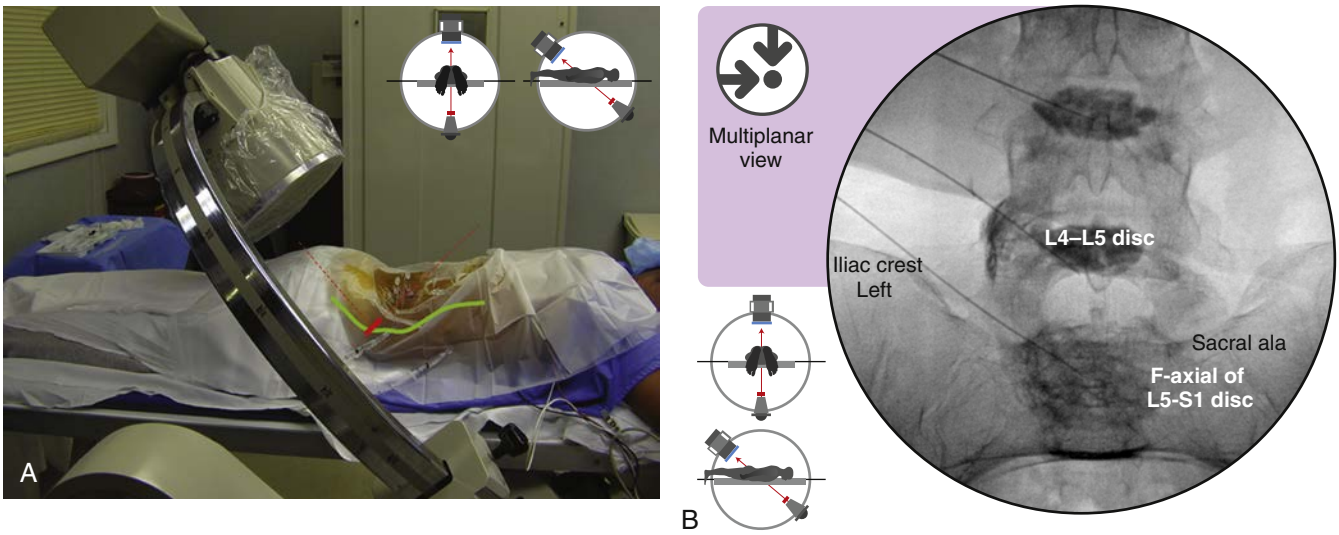

Fig. 17B.7. Fluoroscopic axial (F-axial) view. **A,** Fluoroscope setup for the F-axial view. Note that as a result of patient lordosis (simulated in green), the L5-S1 disc is oriented as simulated in red. The "true" anteroposterior view of L5-S1 is obtained by lining up the end plates parallel to the simulated red disc (not shown). By tilting almost 90–degree caudad and perpendicular to the simulated red disc, the F-axial view is obtained. **B,** The F-axial view obtained by tilting the image intensifier as caudad as possible. The bottom needle is entering L5-S1. Note that the needle angle enters the L5-S1 disc parallel to a "true" anteroposterior view. The contrast is seen to be intranuclear and spreads diffusely through the disc.

Suboptimal Images

The F-axial view provides valuable visualization, usually limited to the L5-S1 disc. It is analogous to a fluoroscopic version of axial computed tomography, and it can help to confirm the needle tip's position within the disc during the procedure (i.e., nucleus pulposus versus annulus fibrosis placement) and to detect the purely annular spread of contrast without accompanying the nuclear contrast flow.

If the F-axial view detects only the annular flow of contrast without the concomitant nuclear flow, then the needle position should be appropriately adjusted and disc stimulation performed again to avoid a false-positive or false-negative diagnosis.

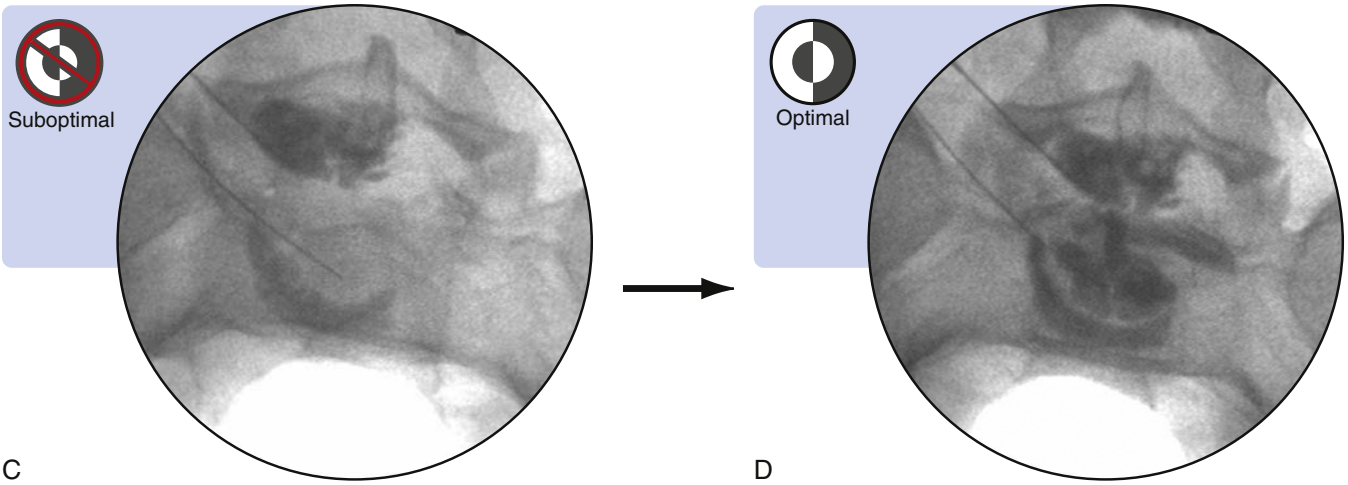

Fig. 17B.7. cont'd C, The F-axial view after needle repositioning (bottom needle) because of initial suboptimal annulus fibrosis placement. **D,** The F-axial view of the same case as in *C*, with the needle repositioned (bottom needle) and the contrast re-injected now with an optimal pattern. Note that the F-axial view enabled the intra-procedure visualization and correction of the annular injection seen in part *C* of this figure, which was not as evident with only the anteroposterior and lateral views.

Reference

1. Furman MB, Reeves RS, Lee TS, Sthalekar ND. Fluoroscopic axial imaging in percutaneous lumbosacral procedures: an underutilized technique. *Pain Physician*. 2006;99(3):199–206.

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CHAPTER 18

Thoracolumbar Spinal Cord Stimulation

Ruby E. Kim, Luis Baez-Cabrera, and Michael B. Furman

Spinal cord stimulation (SCS) is generally used as a last resort for patients who no longer have other treatment options. Typically, stimulators are used for patients who have undergone prior spine surgery with scarring. The best outcomes are achieved for patients with a larger component of neuropathic, appendicular, as opposed to axial, pain. Other indications include complex regional pain syndrome, painful peripheral neuropathy, and phantom limb pain. In Europe, SCS has been described for treatment of vascular claudication and angina.

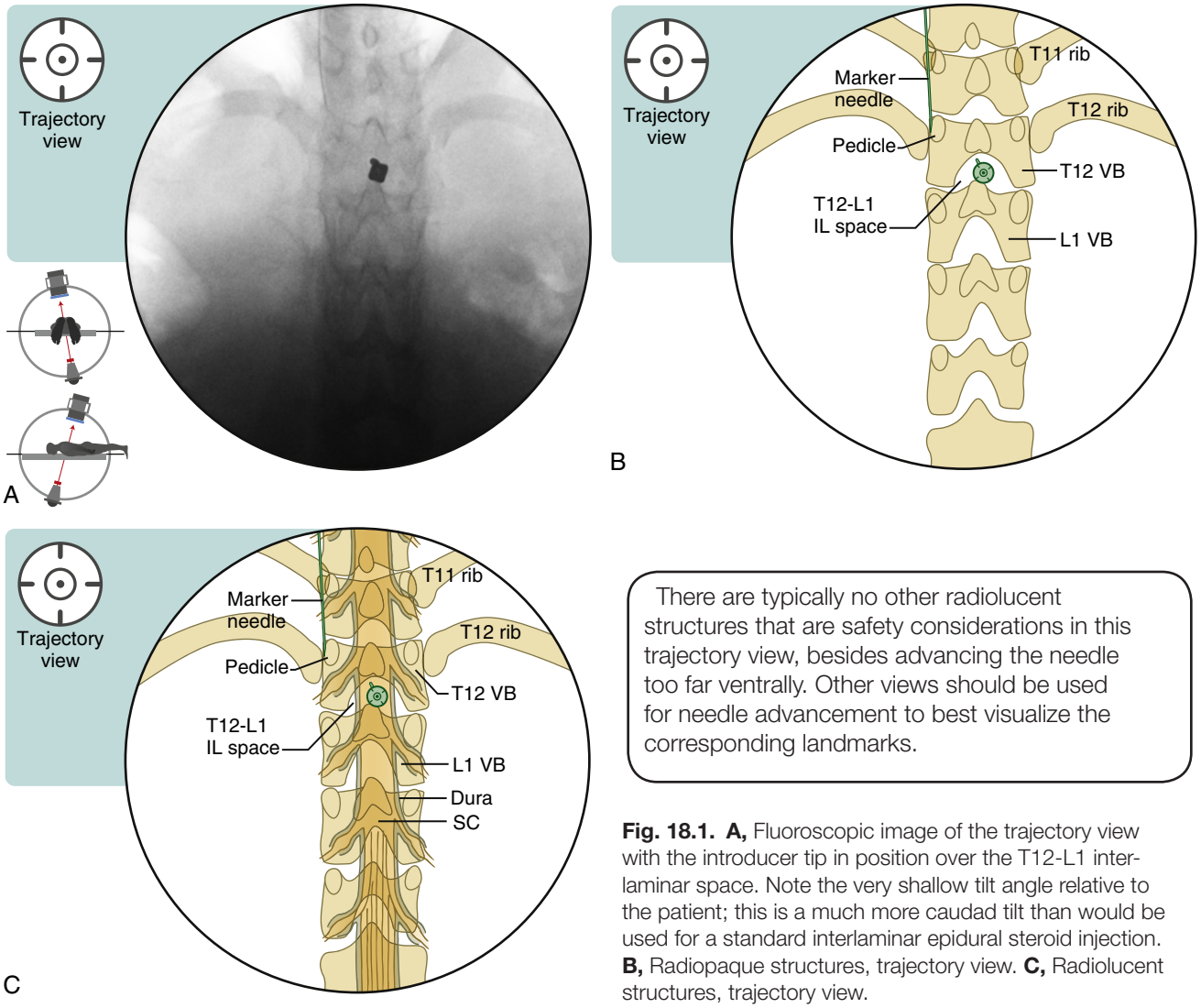
The technique described in this chapter follows the algorithm that has been described elsewhere in this book. In particular, we use a trajectory view, obliquing and tilting the fluoroscope to optimize the introducer needle entry point. Alternatively, one may count down and enter 1.5 to 2 pedicles below the target entry point, as demonstrated in Fig. 18.2.

Note that the angle of the needle is much shallower (i.e., approaching as parallel as possible to the patient's body) than that required for an interlaminar injection so that the stimulator lead will smoothly exit the needle into the posterior epidural space. The stimulator lead will ride along the patient's midline until the electrodes reach the level at which the patient's pain symptoms are covered, often between T7 and T8 for axial pain and between T8 and T10 for appendicular pain. Because we are using trajectory, contralateral oblique, and lateral safety views, it is not necessary to step off of the lamina with our described technique.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 18.1)

- Confirm the targeted interlaminar space with the anteroposterior (AP) view. (See Fig. 18.1; T12-L1 is targeted here.)
- Pearl: The potentially safest needle entry point is at or below L2-L3 that is below the conus medullaris where the dura is more distensible, averting needle injury to the SC. This, of course, assumes there is no stenosis or other pathology at the entered level. However, the safety of entering at a lower level must be balanced with the need to navigate the lead further to the target location.
- Place a "marker" needle at one of the levels to assist counting in various views (left T12 pedicle in this example).
- With a radiopaque marker at the targeted level, tilt the C-arm image intensifier as caudally as possible while viewing the targeted interlaminar space to obtain the trajectory view. The amount of caudad tilt will be restricted by the patient's body habitus, physically limiting the ability to tilt the image intensifier.
- Slightly oblique the C-arm contralateral to the introducer entry side so that the introducer will be set up to help guide the stimulator lead. The lead will have a tendency to travel contralateral to the side of entry, thereby making this technique an efficient method of facilitating proper lead positioning.
- Anesthetize the skin over the targeted interlaminar space, and use an 18-G, 1.5-inch needle to dilate the skin. Remove the 18-G needle, and use the introducer needle to obtain the trajectory needle view. Because this is the trajectory view, the needle entry position should be parallel to the C-arm beam. Note that the angle of the needle is as shallow as possible, as described in this chapter's introduction (Fig. 18.1).



There are typically no other radiolucent structures that are safety considerations in this trajectory view, besides advancing the needle too far ventrally. Other views should be used for needle advancement to best visualize the corresponding landmarks.

Fig. 18.1. A, Fluoroscopic image of the trajectory view with the introducer tip in position over the T12-L1 interlaminar space. Note the very shallow tilt angle relative to the patient; this is a much more caudad tilt than would be used for a standard interlaminar epidural steroid injection. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

As an **alternative to a direct trajectory view**, one may instead choose the targeted interlaminar needle tip entry and enter the skin approximately 1.5 pedicles below it. For thinner patients (lower body mass index [BMI]) or larger patients (higher BMI), adjust the entry point accordingly (Fig. 18.2). This alternate technique is especially helpful in situations when the intensifier cannot physically tilt enough because of the patient's obesity or large buttock region.

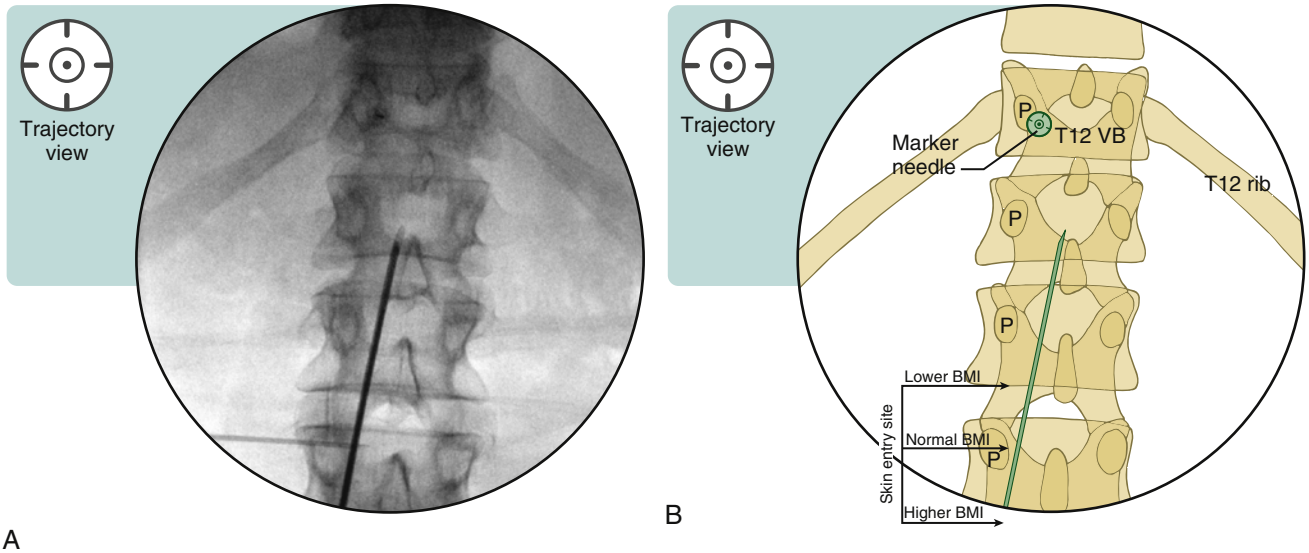


Fig. 18.2. Alternate needle entry site (trajectory) in the anteroposterior (AP) view. In most individuals (normal body mass index [BMI]), the needle entry point is suggested to be one and half pedicle (P) distance from the T12-L1 disc space (or targeted intervertebral disc space). **A,** Fluoroscopic AP view showing the stimulator placement needle entering 1.5 pedicles (left L3) below the (T12-L1) target. There is a marker needle at T12 and another needle placed on the patient's back so that it crosses the stimulator placement needle as it enters the skin. **B,** Corresponding diagram. In individuals with lower and higher BMIs, adjust the entry appropriately. This is to accommodate the decrease or increase in subcutaneous tissues between the skin surface and target.

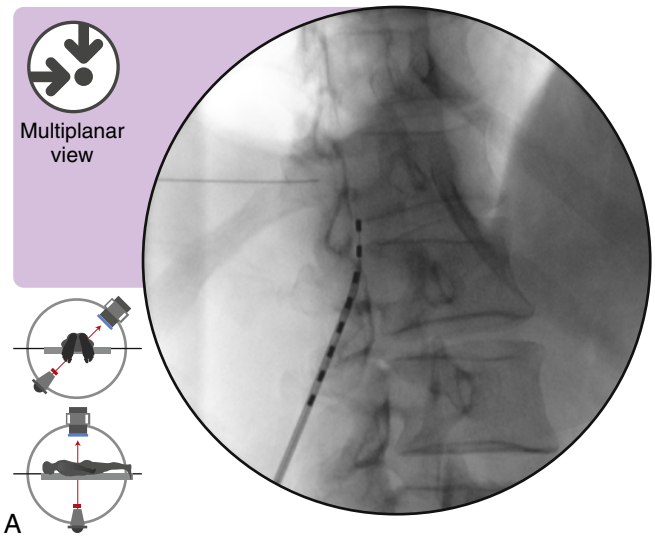
Optimal Needle Position in Multiplanar Imaging

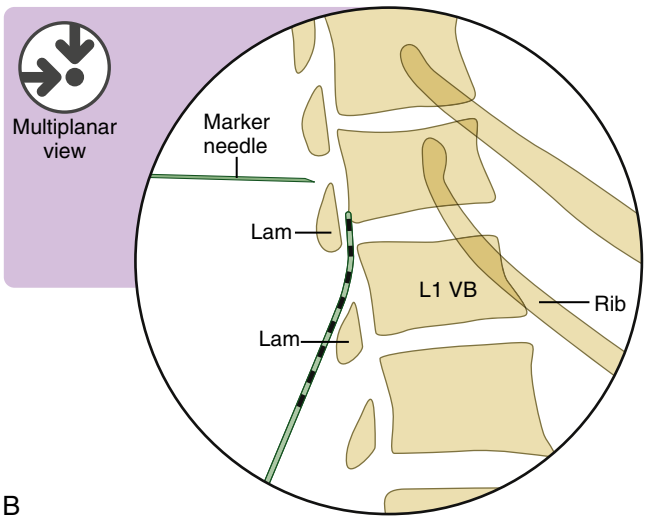
- Tilt the C-arm cephalad to confirm that the needle tip is over the lamina of L1. Advance the introducer tip until it approaches the superior edge of the L1 lamina, maintaining the tip midline. It does not need to touch the periosteum. Do an AP to confirm that the needle tip is midline, then:
- Confirm the safety/depth of this position with a contralateral oblique (CLO) and/or lateral view. With this approach, the needle does not need to be "walked off" of the lamina. Instead, the needle is safely and efficiently advanced between the superior and inferior lamina until it reaches the ventral interlaminar line in CLO or spinolaminar line in the lateral view (see Fig. 18.3).
- Perform the loss of resistance (LOR) technique to enter the epidural space using saline, air, K wire (lead blank), or the SCS lead. Use minimal saline for the "LOR" because it can potentially increase impedance.

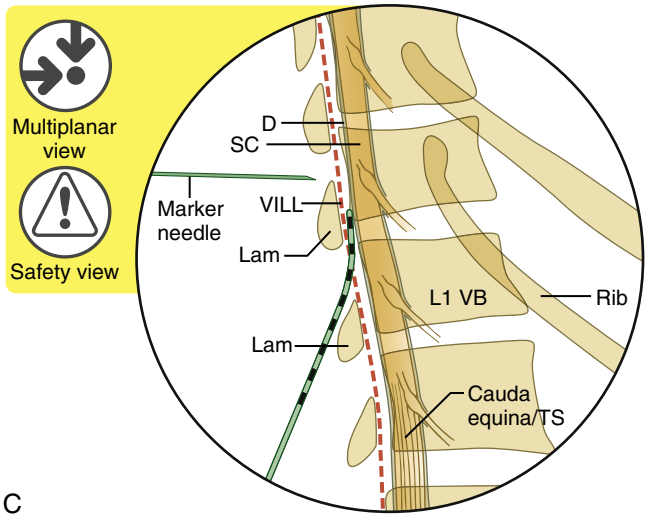
  Other views should be used for needle advancement to best visualize corresponding landmarks.

Needle Positioning in the Contralateral Oblique View (Fig. 18.3)

After the trajectory view and a brief AP view confirmation that the tip is approaching the midline, use this view for driving between the lamina to approach the epidural space as the needle tip gently crosses the ventral interlaminar line (VILL). This view may be used to adjust the needle trajectory and to choose a more superior level (without removing the introducer needle) thereby achieving a shallower angle before traversing between the lamina and approaching the VILL.







Contralateral Oblique Safety Considerations

Confirm epidural as crossing the VILL. Avoid puncturing the dura (D) and contacting the SC.

Fig. 18.3. A, Fluoroscopic image of the contralateral oblique view with the introducer tip in place and with the stimulator lead beginning to advance. This view enables the visualization of the lamina *(L)*, which will facilitate the visualization of the interlaminar space. Use this view to safely and efficiently navigate between the lamina to the ventral interlaminar line (VILL). This view may be used to choose a more superior level (without removing the introducer needle), thereby achieving a more shallow angle before traversing between the lamina and approaching the VILL. Intermittently switch to the AP view to confirm a midline approach. **B,** Radiopaque structures, contralateral oblique view. **C,** Radiolucent structures, contralateral oblique view. Compare with computed tomography (CT) in Fig. 3.22.

Needle Positioning in the Anteroposterior View (Fig. 18.4)

This view is first used to confirm a midline introducer tip. After confirming epidural placement (other views), this is the ideal view for lead advancement.

- Return to the AP view to navigate the stimulator lead cephalad while maintaining it in the midline.
- Use the introducer needle's bevel combined with the steerable lead to guide the electrodes to their final target location, driving them slightly lateral toward the painful side.
- Do not let the lead fall laterally and ventrally into the gutter (see Fig. 18.11).

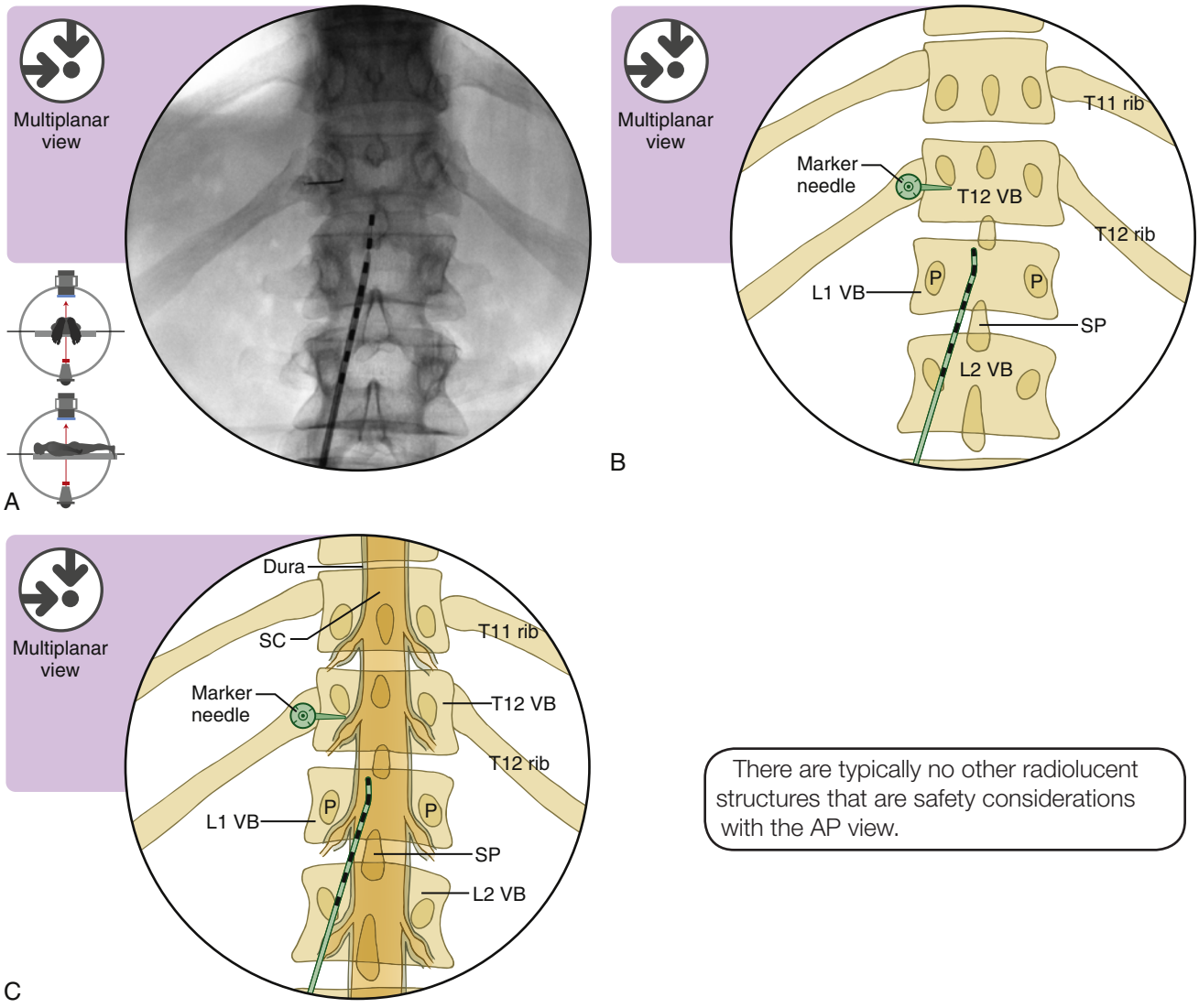
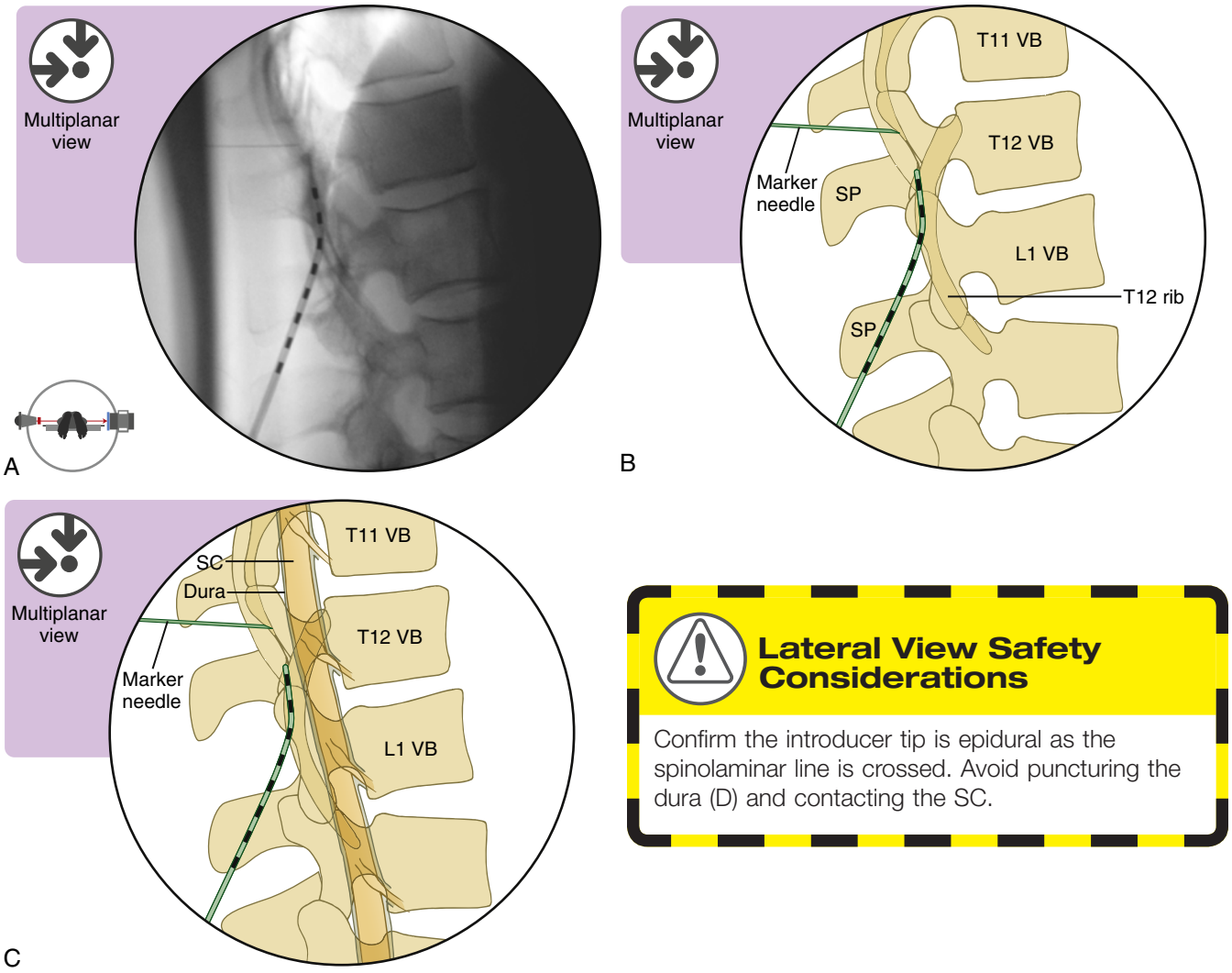


Fig. 18.4. A, Fluoroscopic image of an anteroposterior view with the introducer tip as midline as possible and with the stimulator lead beginning to advance. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view. This view is used to confirm the midline entry as the VILL/spinolaminar line approach is confirmed in other views. After epidural confirmation, this is also the ideal view for lead advancement. (Marker needle over left T12 pedicle.)

Needle Positioning in the Lateral View (Fig. 18.5)



Lateral View Safety Considerations

Confirm the introducer tip is epidural as the spinolaminar line is crossed. Avoid puncturing the dura (D) and contacting the SC.

Fig. 18.5. A, Fluoroscopic image of a lateral view with the introducer tip in place and the stimulator lead beginning to advance. Note the shallow angle of the introducer, which enables easier manipulation of the stimulator lead. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Spinal Cord Stimulator Positioning (Figs. 18.6 and 18.7)

We recommend a minimum of two views, including the AP and either (or both) of the "true" lateral or contralateral oblique views, to confirm final lead positioning.

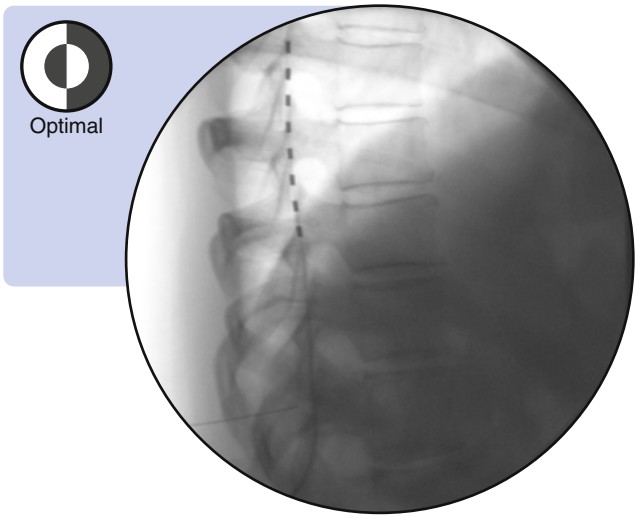


Fig. 18.6. Fluoroscopic image of a lateral view with the introducer tip in place and the stimulator lead in its final position at the T8 level. Note that because of the shallow introducer entry angle, there is a smooth transition as the lead gently enters into the epidural space. This enables easier lead navigation. (Marker needle at T12.)

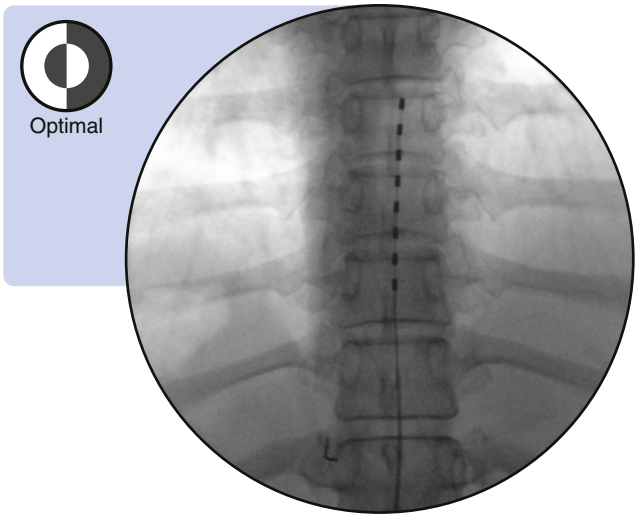
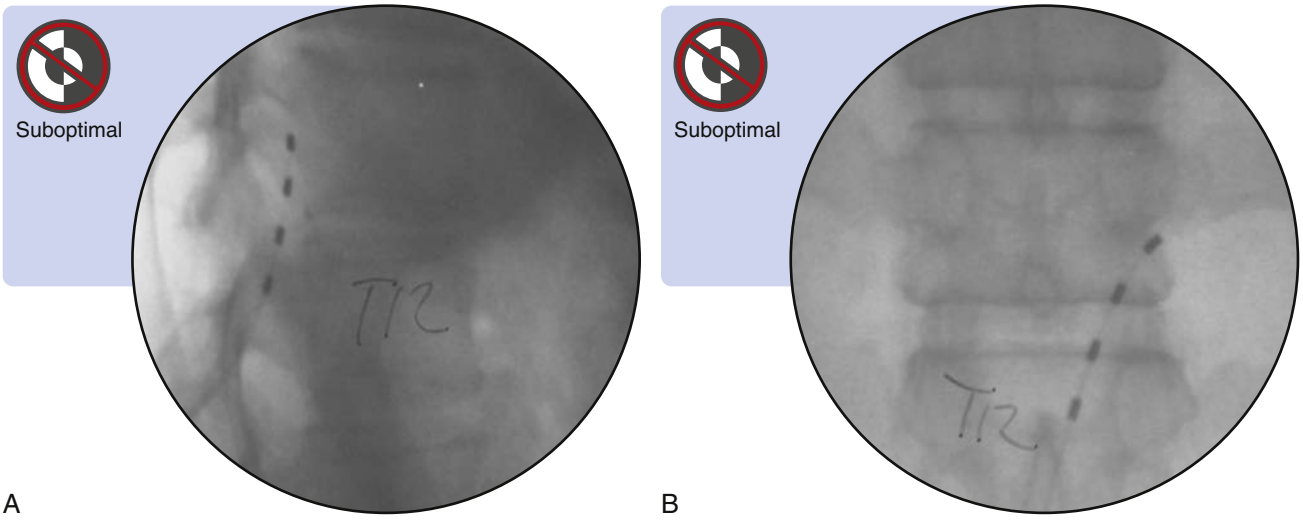


Fig. 18.7. Fluoroscopic image of an anteroposterior view with the stimulator lead in its final position, slightly right of the midline. (Marker needle at T12.)

Suboptimal Position Views (Figs. 18.8 to 18.11)



A B

Fig. 18.8. A, Suboptimal fluoroscopic image of a lateral view with the stimulator lead too far ventral. **B,** This fluoroscopic image of the same patient, as shown in 18.8A, is an anteroposterior view demonstrating that the stimulator lead is exiting the intervertebral foramen.

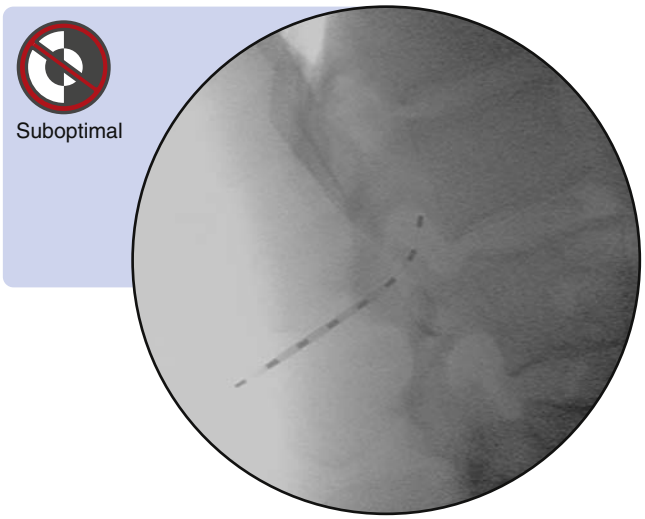


Fig. 18.9. Suboptimal fluoroscopic image of a lateral view with the lead stimulator too ventral. The initial approach was not shallow enough (i.e., too perpendicular to the patient). Therefore, the lead wire did not have a "good landing," which resulted in ventral placement. This can often result in patient discomfort. Once the lead is in the lateral gutter, it is more difficult to reposition the stimulator lead midline and to drive it superiorly into the correct location.

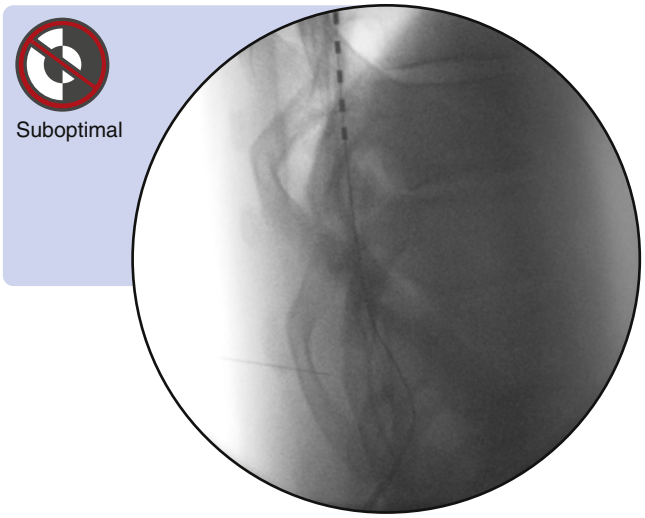


Fig. 18.10. Suboptimal fluoroscopic image of a lateral view with the lead stimulator buckling. The lead was not advancing in the anteroposterior (AP) view because of an obstruction within the canal. This will typically result in patient discomfort.

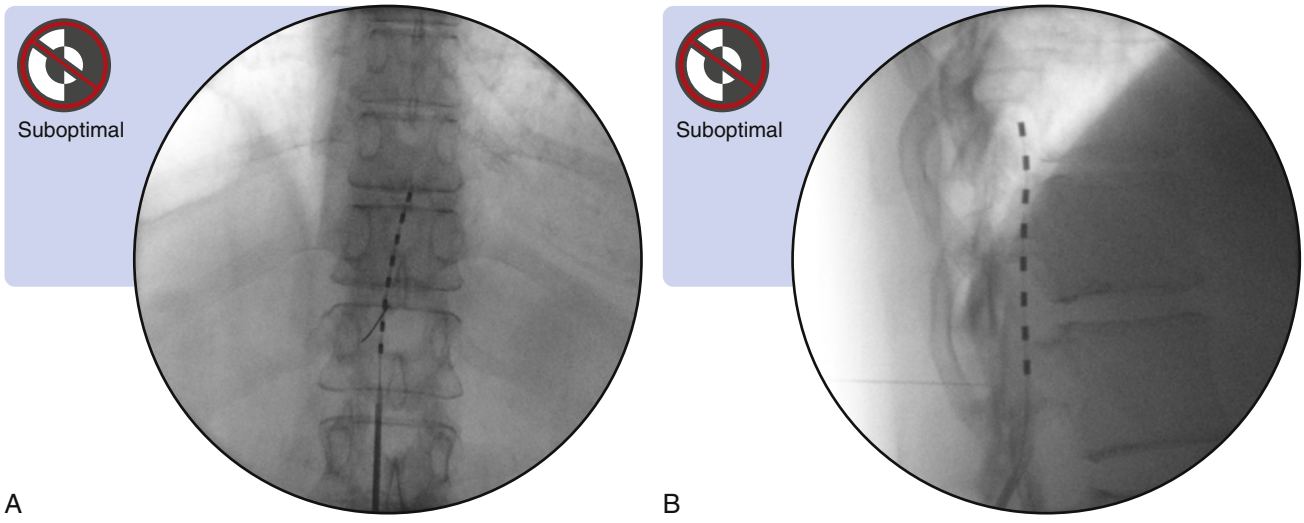


Fig. 18.11. A, Suboptimal fluoroscopic image of an anteroposterior (AP) view with the lead stimulator slightly off of the midline. When the stimulator was turned on, the patient complained of abdominal stimulation. **B**, Lateral view demonstrates that the lead has fallen ventrally and laterally into the lateral gutter. This example is shown to emphasize the importance of staying midline to prevent this.

Alternate Retrograde Spinal Cord Stimulator Placement (Fig. 18.12)

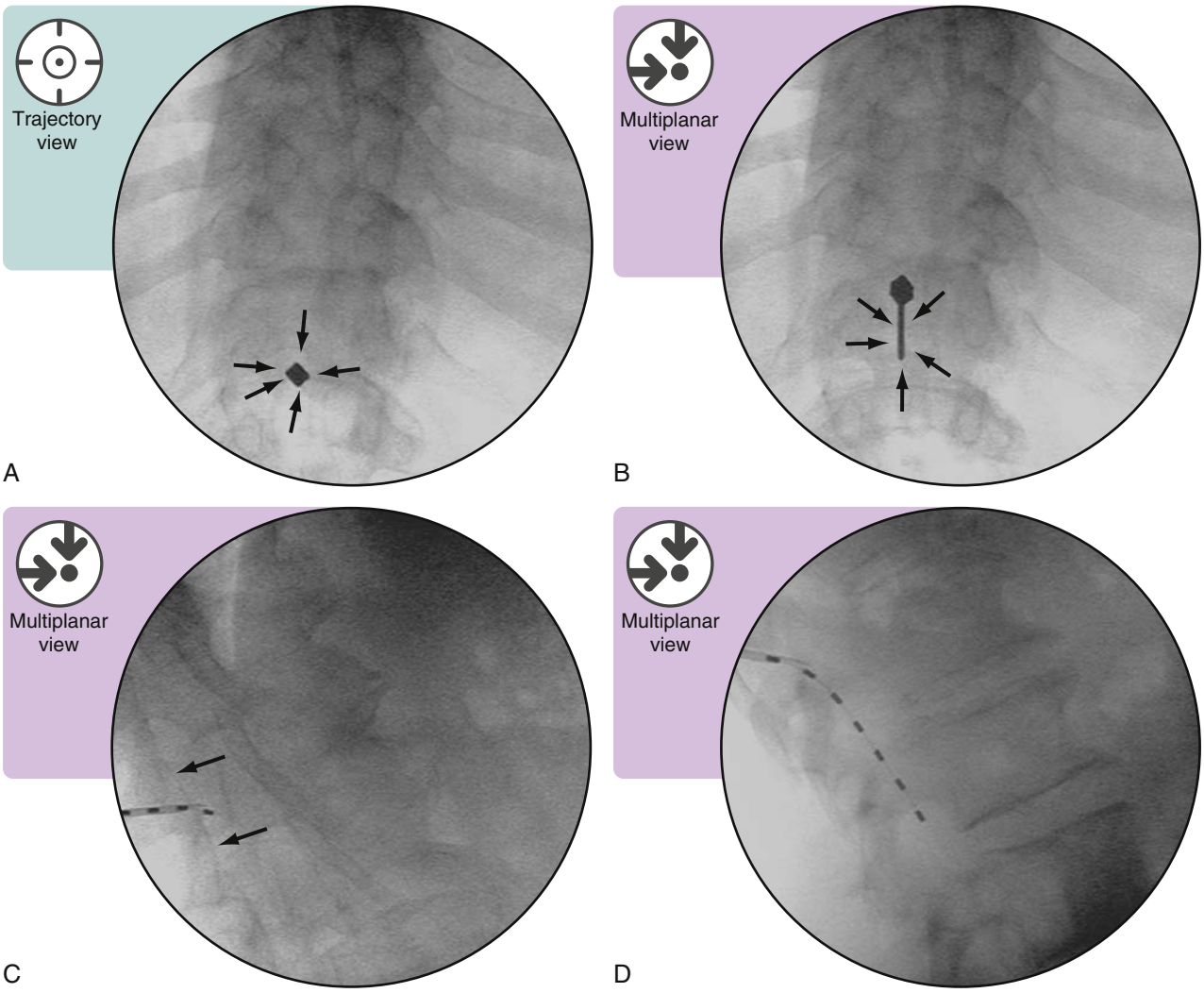
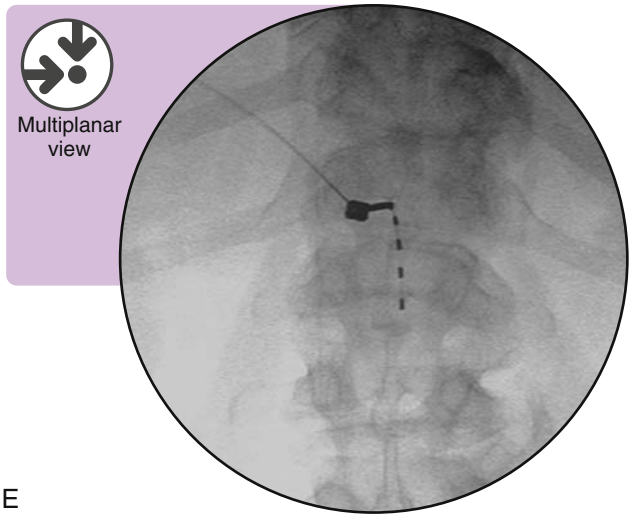
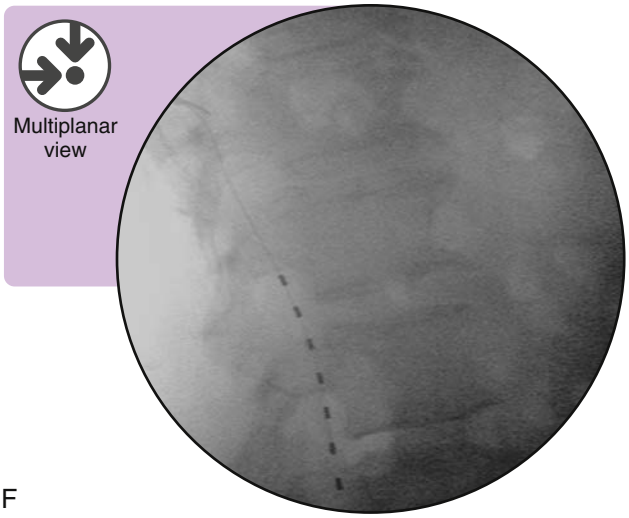


Fig. 18.12. Series of retrograde spinal cord stimulator (SCS) placement images: this patient has pain that originated from the upper right lumbar segments and had previous lower lumbar surgery. An SCS is placed with a retrograde technique to navigate the lead down into the right upper lateral "gutter." **A,** Using a trajectory view for initial needle placement enables visualization of a direct, unobstructed cranio-caudad trajectory for retrograde interlaminar needle placement. Tilt the image intensifier cephalad as much as the anatomy allows to see an unobstructed interlaminar space. **B,** Another view with a more caudad tilt confirming the tip is approaching midline. Use of a trajectory and contralateral oblique view technique **(C)** is well suited for this procedure because of the challenge of identifying and efficiently accessing the midline **(B)** epidural space with a retrograde cranio-caudal trajectory. The arrows indicate the interlaminar space in **(A)** and **(B)**. The arrows indicate the lamina in **(B)**. Initial multiplanar views **(C–E)** confirm the midline to be a safe, epidural space access. Final views **(F, G)** demonstrate the optimal final lead position.

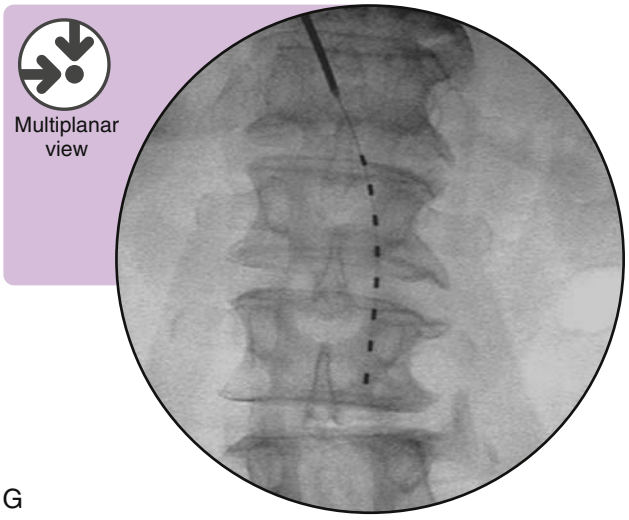
Continued



E



F



G

Fig. 18.12, cont'd

Reference

1. Furman MB, Jasper NR, Lin H. Fluoroscopic contralateral oblique view in interlaminar interventions: a technical note. *Pain Med*. 2012;13(11):1389–1396.

CHAPTER 19

Vertebral Augmentation (Vertebroplasty/ Kyphoplasty): Transpedicular Approach

Ryan Reeves, William A. Ante, Michael E. Frey, and Michael B. Furman

Vertebral body compression fractures are estimated to occur approximately 700,000 times each year. This presents a significant public health challenge from the standpoints of morbidity, mortality, and health care expenditures. Pain reduction, vertebral body stabilization, and rapid return to function are paramount for those who are affected with this disabling condition.

Although alternative techniques have been described, the approach described here involves the use of a trajectory view as the primary approach. The vertebral body is cannulated in the trajectory view (see Appendix 1). Fig. 19.11 demonstrates the angulation of the needle trajectory in the lateral view with various fracture pattern scenarios.

The described procedure has three phases: (1) transpedicular advancement, (2) vertebral body advancement and balloon inflation for kyphoplasty, and (3) bone cement injection. As is emphasized throughout this text, safety is mediated by judiciously using multiplanar views during the procedure.

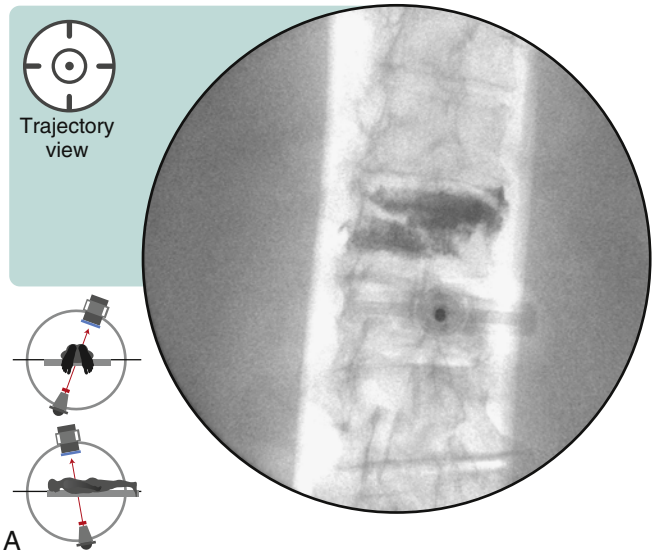
A key operational difference between kyphoplasty and vertebroplasty lies in the placement of the working cannula. During kyphoplasty, when the osteo introducer anchors 1 to 2 mm ventral to the posterior vertebral body (see Fig. 19.3 A). a biopsy can be taken; alternatively, the drill can be used to create a path for the balloon tamp (see Fig. 19.10 A and B). During vertebroplasty, the introducer cannula is driven from the pedicle toward the midline of the vertebral bone without additional instrumentation. When the cannula tip has docked into the posterior vertebral body (see Fig. 19.3 A), the tip medial to the pedicle is expected to be visualized in the anteroposterior view; however, advancement should always be done in the lateral view to protect the great vessels.

The oblique transpedicular view is identical to the trajectory view (Fig. 19.1), as previously described.

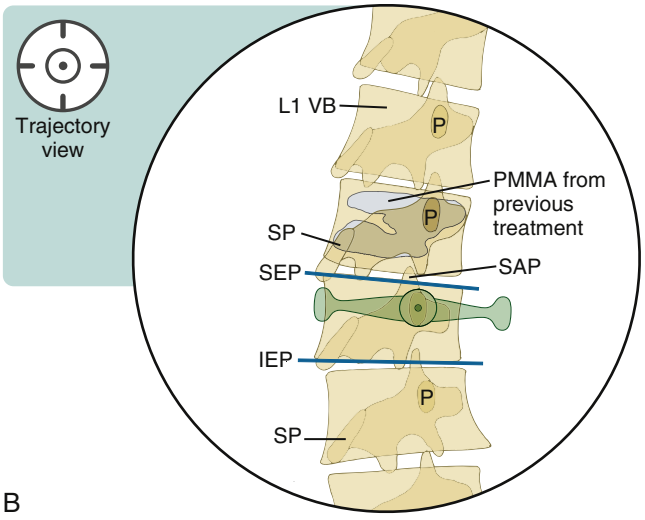
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Transpedicular Advancement: Trajectory View (Fig. 19.1)

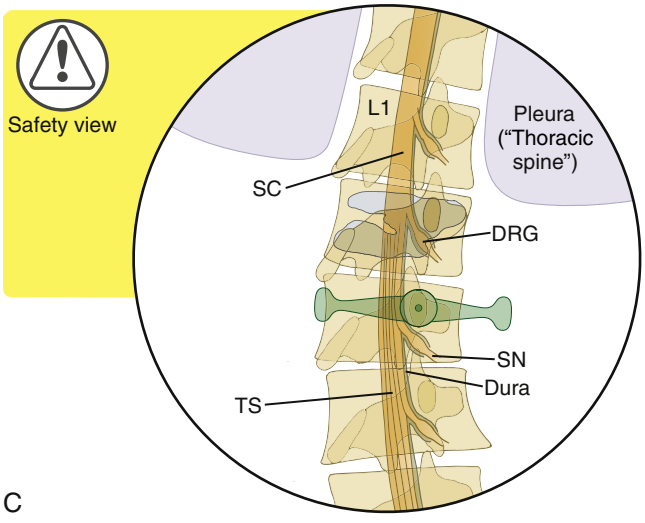
- **Confirm the level** (with the anteroposterior view).
- **Tilt** the C-arm to line up the **inferior endplate** of the vertebral body to be treated.
- **Ipsilateral oblique** approximately 10 to 20 degrees so that the **pedicle appears as a clock face.**
- Position the pedicle in the oblique view so that it is completely superimposed within the outline of the vertebral body.
- The transpedicular entry point is the **superior lateral quadrant** (i.e., the 10 or 2 o'clock position for left or right entry, respectively) for fractures occurring along the superior end plate (majority of fractures).
- For biconcave and planar fractures, entering in the middle of the pedicle will provide optimal placement (see Fig. 19.11).
- For inferior end plate fractures, a 7 or 5 o'clock position for cannulation should be achieved.
- Anesthetize the needle tract and periosteum overlying the pedicle.
- Nick the skin (No. 11 blade for kyphoplasty or an 18-G needle for vertebroplasty).
- Insert the osteo introducer device or the bone needle, and place the tip onto the pedicle.
- Gently tap the bone needle with a mallet to create a starting hole.
- Advance the needle with gentle manual pressure or mallet tapping.



A



B



C

Trajectory View Safety Considerations

- Avoid the spinal cord and thecal sac (TS) contents by staying lateral to the medial border of the pedicle.
- Avoid the superior and inferior nerve roots and spinal nerves by staying within the inferior and superior pedicular borders.
- Avoid pneumothorax during thoracic vertebral body augmentation by avoiding violation of the lateral wall of the vertebral body by traversing in a lateral-to-medial intrapedicular pathway.

Fig. 19.1. A, Fluoroscopic image of a trajectory view with the affected L3 vertebral body "squared off" with the pedicle in line with the vertebral body. Cannulate the vertebral body in the trajectory view. **B,** Radiopaque structures. **C,** Radiolucent structures.

Multiplanar Views During Transpedicular Advancement (Figs. 19.2 and 19.3)

ANTEROPOSTERIOR VIEW

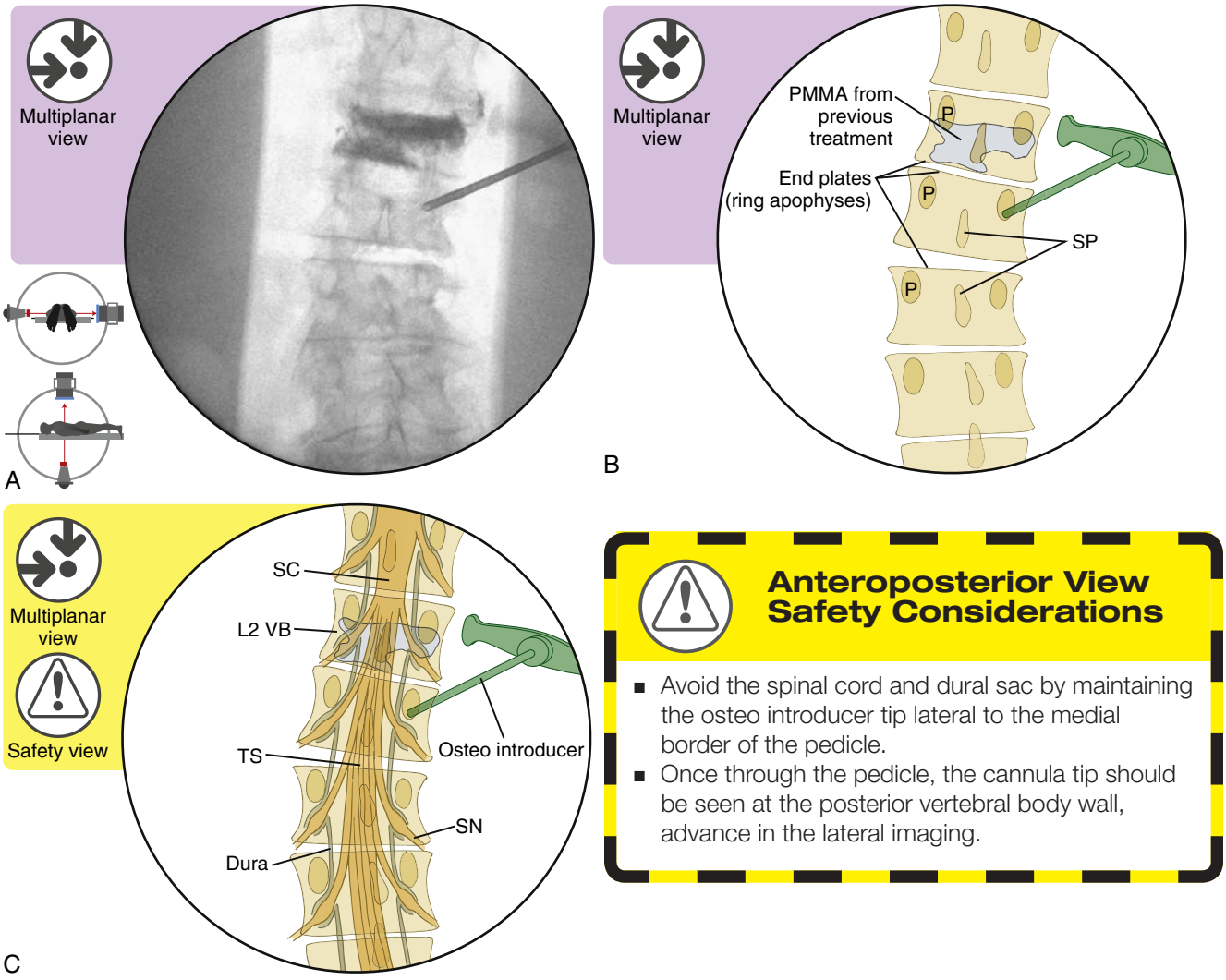
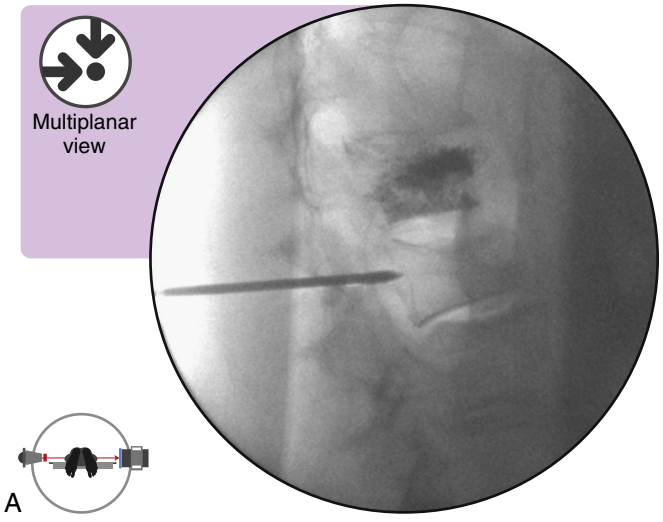
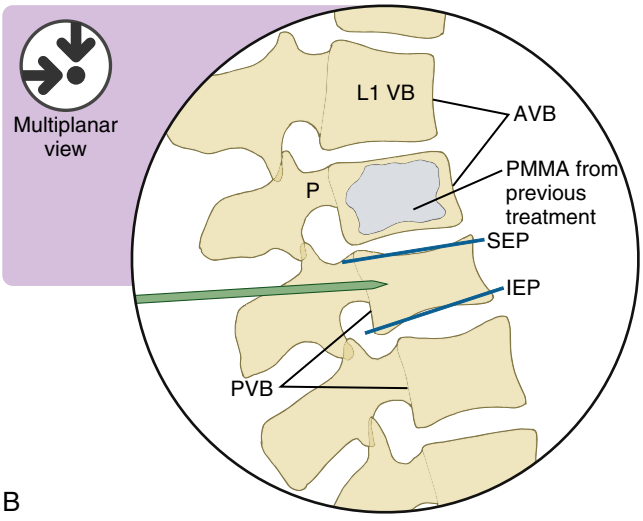


Fig. 19.2. A, Fluoroscopic image of an anteroposterior view with the osteo introducer cannula passing through the right L3 pedicle. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

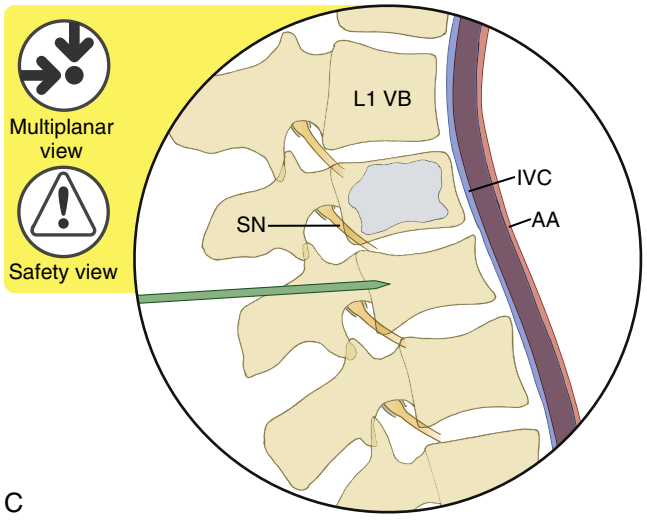
LATERAL VIEW



A



B



C

Lateral View Safety Considerations

- Breaching the anterior vertebral body cortex could damage the great vessels (i.e., the aorta and inferior vena cava) or the common iliac vessels when advancing through the L4 and L5 vertebral bodies.
- A misaligned trajectory angle (e.g., severe cephalad to caudad) could breach the inferior wall of the pedicle and result in spinal nerve damage.

Fig. 19.3. A, Fluoroscopic image of a lateral view with the osteo introducer cannula passing through the pedicle. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Multiplanar Views During Vertebral Body Advancement

This is not the safety view for this procedure because the osteo introducer tip has already safely traversed the pedicle. Use the lateral view (Fig. 19.5) for needle advancement safety considerations during vertebral body advancement.

ANTEROPOSTERIOR VIEW, VERTEBRAL BODY ADVANCEMENT (FIG. 19.4)

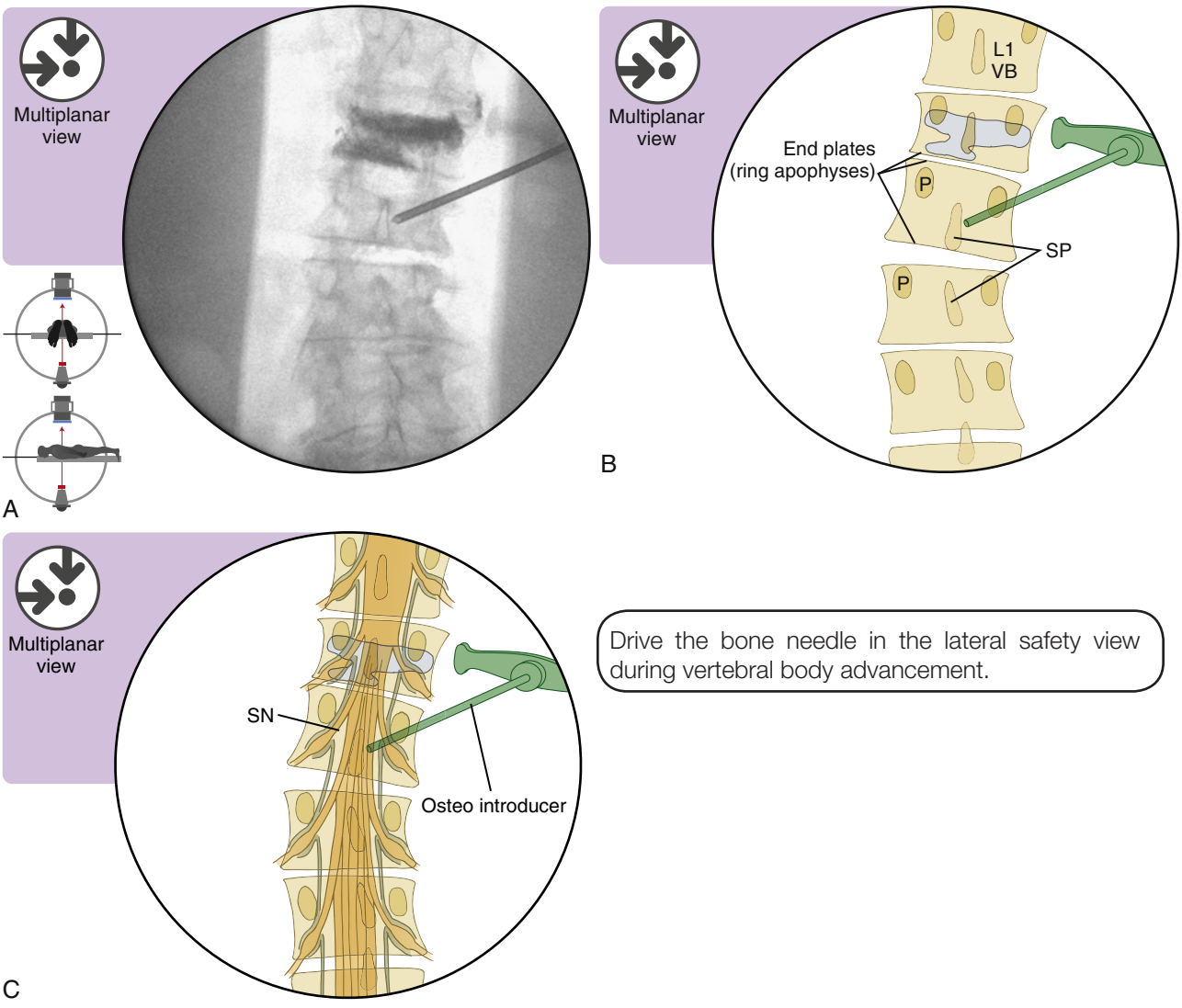


Fig. 19.4. A, Fluoroscopic image of a final anteroposterior view with the osteo introducer cannula in the vertebral body. Once the instrumentation passes through the pedicle, the anteroposterior view should show the cannula tip as being medial to the pedicle. **B,** Radiopaque structures, final anteroposterior view. **C,** Radiolucent structures, final anteroposterior view.

LATERAL VIEW, VERTEBRAL BODY ADVANCEMENT (FIG. 19.5)

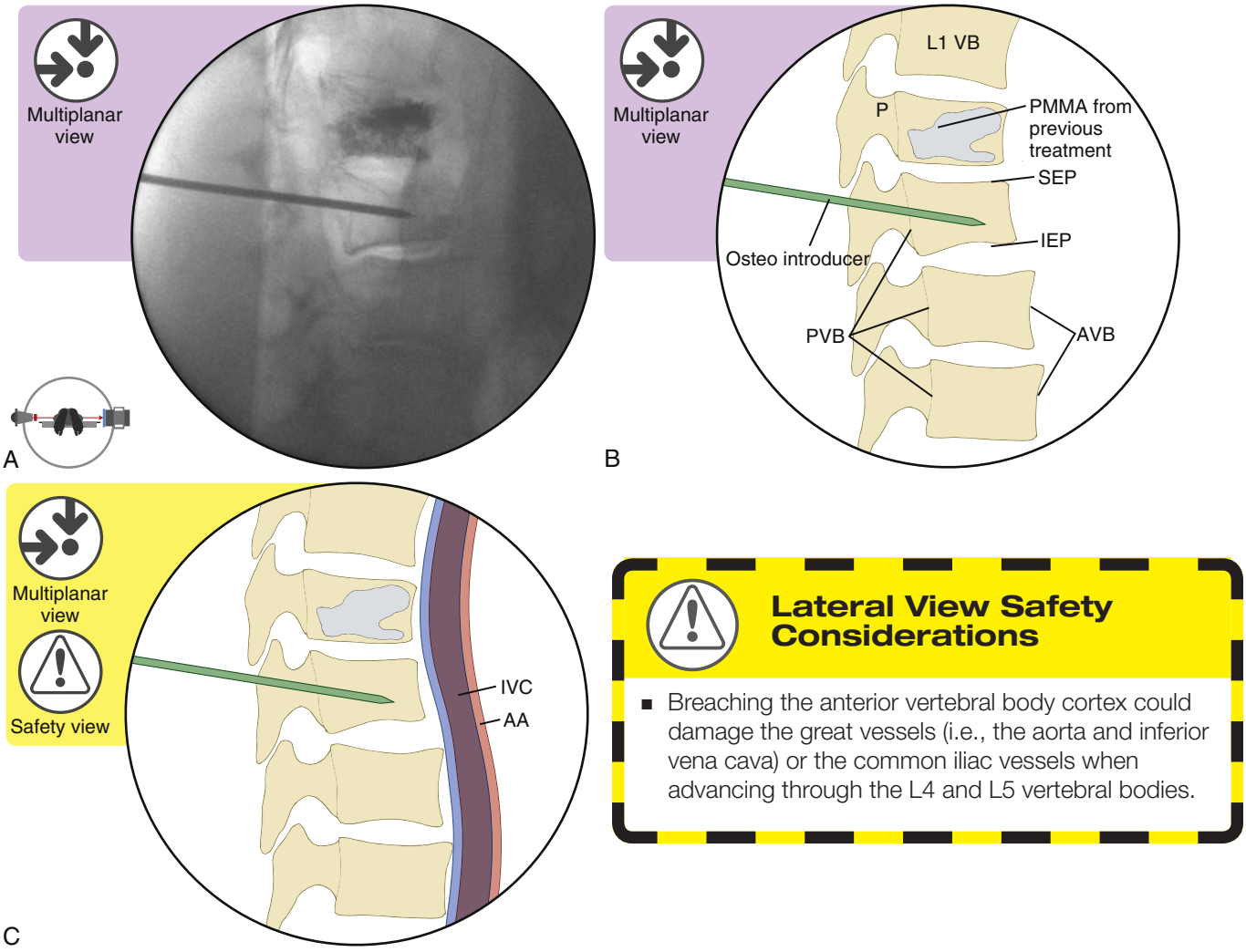


Fig. 19.5. **A,** Fluoroscopic image of a final lateral view with the osteo introducer cannula in the vertebral body. **B,** Radiopaque structures, final lateral view. **C,** Radiolucent structures, final lateral view.

Multiplanar Views During the Injection of Bone Cement

SAFETY CONCERNS WITH CEMENT INJECTION

- Administer with live real-time fluoroscopy (mostly within the lateral view).
- Inject a half turn (0.5 cc) at a time.
- Monitor for inadvertent leakage posteriorly into the spinal canal or intervertebral foramen.
- The view should be anterior to the vertebral body to visualize inadvertent cement extravasation into the anterior vessels to avert or detect cement pulmonary embolism.
- Routinely STOP to check the anteroposterior view to judge the spread of contrast medium past the midline and evaluate for any inadvertent cement flow lateral to the vertebral body or inside the foramen.
- If there is still a need for administration of more cement, reinitiate cement injection in the lateral view with live fluoroscopy.
- Once adequate spread of contrast is seen toward or past the midline, polymethylmethacrylate (PMMA) injection should be discontinued. The volume injected should roughly equal the amount of contrast injected into the balloon tamp unless adequate interdigitation and spread is seen.

ANTEROPOSTERIOR VIEW, BONE CEMENT INJECTION (FIG. 19.6)

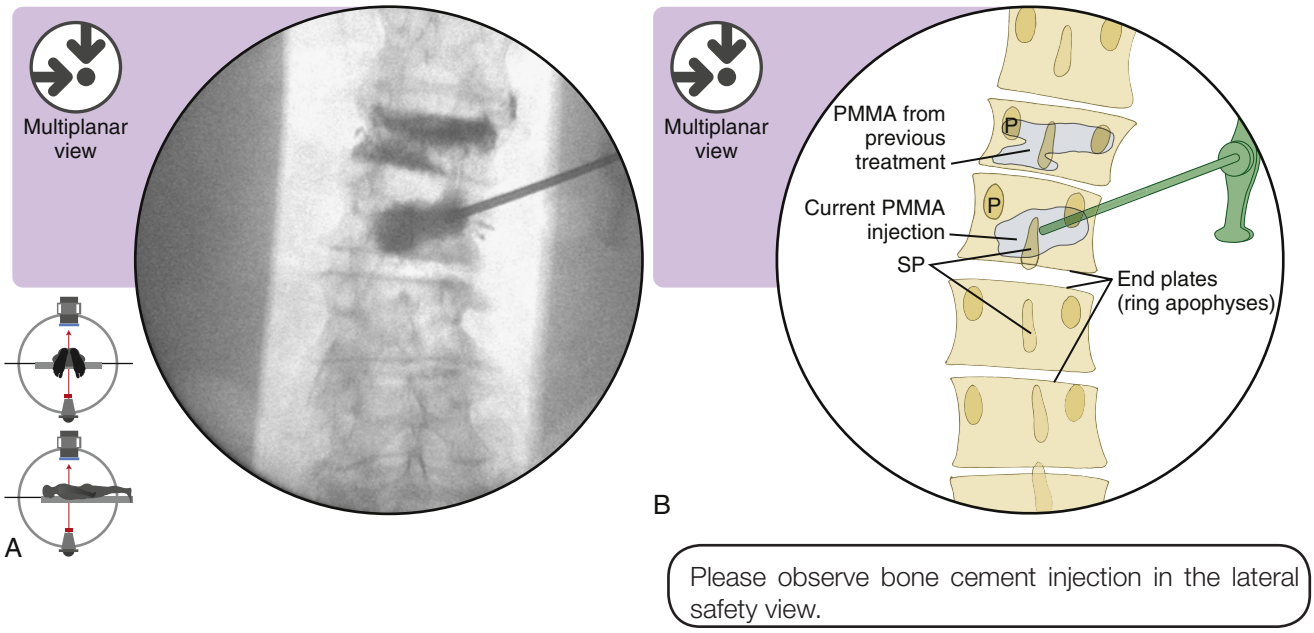


Fig. 19.6. A, Fluoroscopic anteroposterior image with polymethylmethacrylate in the L3 vertebral body with a working cannula. **B,** Radiopaque structures, anteroposterior view.

Anteroposterior View Safety Considerations

- The lateral spread of PMMA outside of the lateral vertebral body should be avoided.
- The spread of PMMA near the pedicles should be avoided to forestall nerve root or spinal cord damage.
- PMMA should only be injected when the needle tip is confirmed in the vertebral body with multiplanar imaging.

LATERAL VIEW, BONE CEMENT INJECTION (FIG. 19.7)

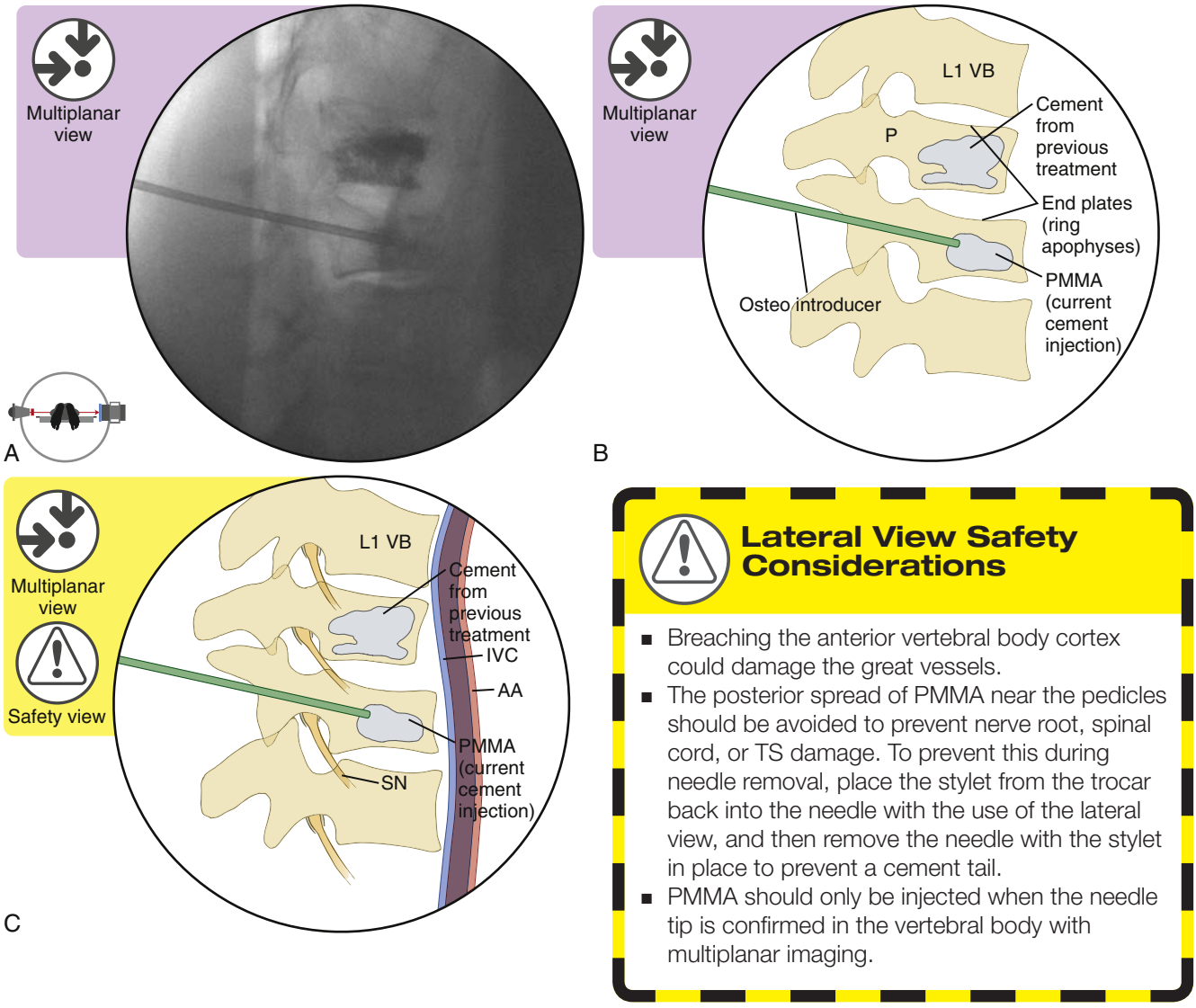

Multiplanar view
A
Multiplanar view
L1 VB
P
Cement from previous treatment
End plates (ring apophyses)
PMMA (current cement injection)
Osteo introducer
B
Multiplanar view
Safety view
L1 VB
Cement from previous treatment
IVC
AA
PMMA (current cement injection)
SN
C
Lateral View Safety Considerations
Breaching the anterior vertebral body cortex could damage the great vessels.
The posterior spread of PMMA near the pedicles should be avoided to prevent nerve root, spinal cord, or TS damage. To prevent this during needle removal, place the stylet from the trocar back into the needle with the use of the lateral view, and then remove the needle with the stylet in place to prevent a cement tail.
PMMA should only be injected when the needle tip is confirmed in the vertebral body with multiplanar imaging.

Fig. 19.7. A, Fluoroscopic lateral image with polymethylmethacrylate injected into the working cannula and in the L3 vertebral body. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Cement Patterns (Fig. 19.8)

Ideal flow should fill any fracture lines. For vertebroplasty, fill the anterior third to half of the vertebral body. For kyphoplasty, fill the cavity that is created by the inflatable bone tamps.

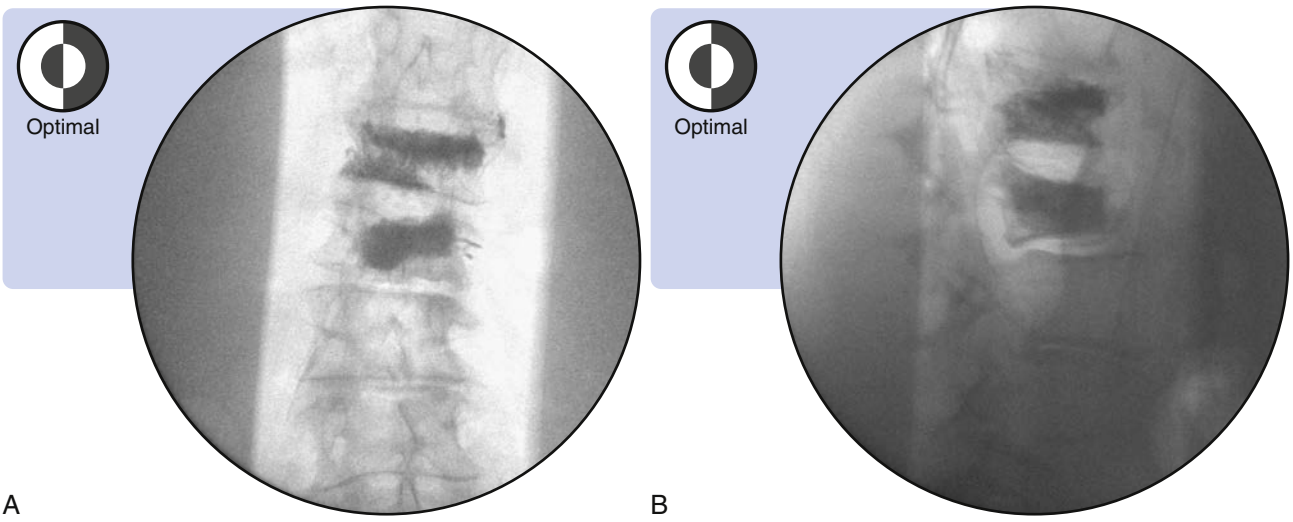


Fig. 19.8. A, Fluoroscopic image of the final anteroposterior view with polymethylmethacrylate in the vertebral body; cannula has been removed. **B,** Fluoroscopic lateral image with polymethylmethacrylate contained in the vertebral body.

Suboptimal Cement Patterns (Fig. 19.9)

Terminate if cement tracks:

- along the posterior third of the vertebral body to avoid foraminal or epidural extravasation,
- outside the cortical boundaries (anterior vasculature),
- or intradiscally (suboptimal, no case reports or studies to date demonstrate deleterious clinical effects).

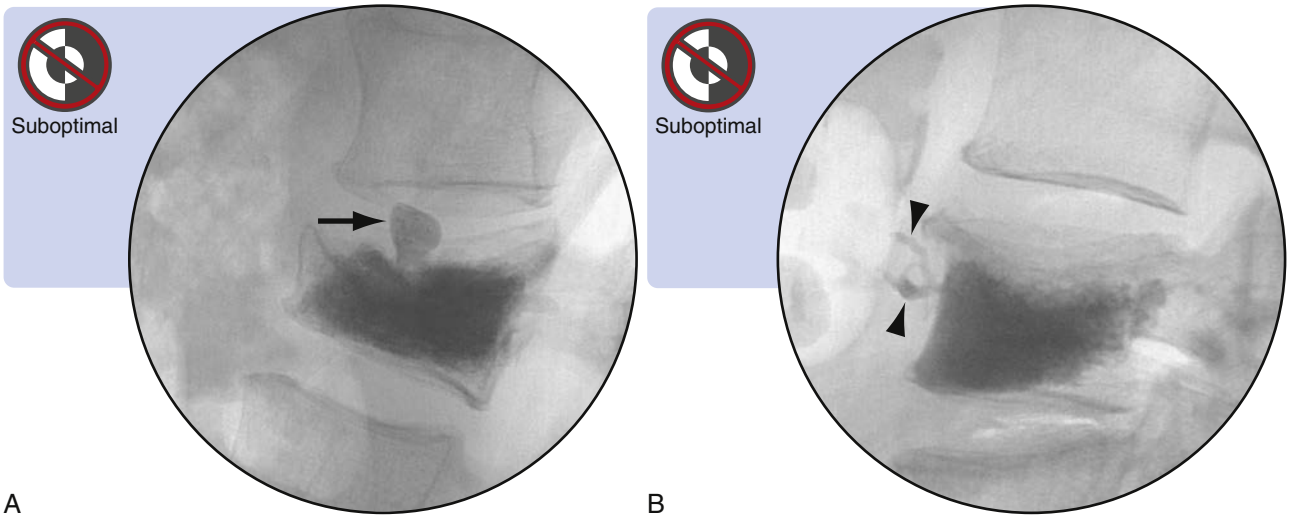


Fig. 19.9. A and **B,** Terminate polymethylmethacrylate filling if cement is seen tracking intradiscally (arrow in A) or outside the cortical boundaries (arrowheads in B).

OPTIMAL KYPHOPLASTY INTRODUCER TIP POSITIONS (FIG. 19.10)

The goal of drilling into the vertebral body is to enable the injection of PMMA as close to the geometric center of the vertebral body near the fracture as possible. The final anteroposterior view should show the tip at midline when the tip of the osteo introducer is near the anterior vertebral body wall in the lateral view.

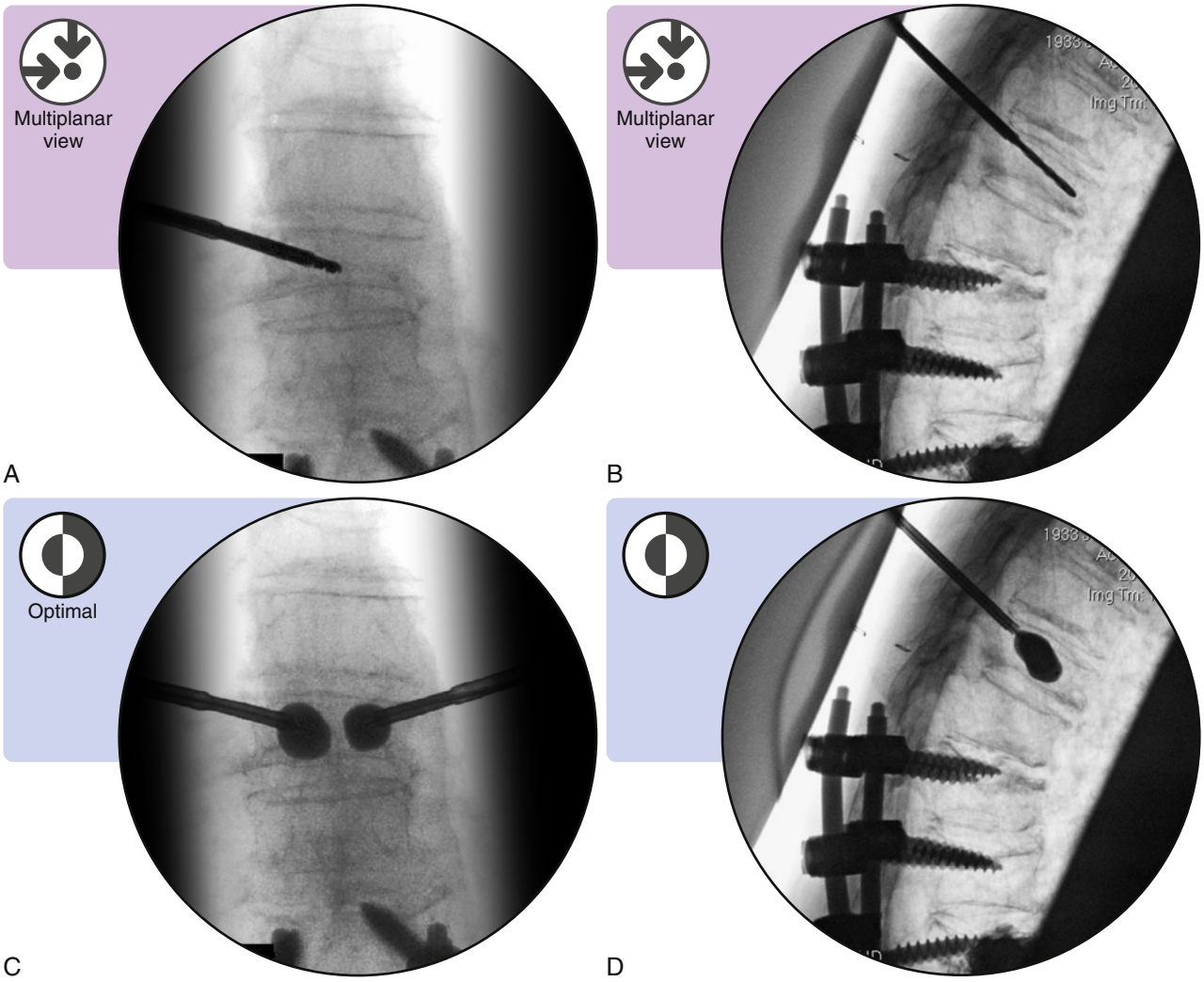


Fig. 19.10. A, Fluoroscopic anteroposterior view with the ideal drill position. The drill tip should be placed approximately 1.5 to 2 mm from the anterior cortex. **B,** Fluoroscopic lateral view with the ideal drill position. **C,** Fluoroscopic anteroposterior view with the ideal inflatable bone tamp with full inflation (i.e., kyphoplasty). **D,** Fluoroscopic lateral view with the ideal inflatable bone tamp with full inflation (i.e., kyphoplasty).

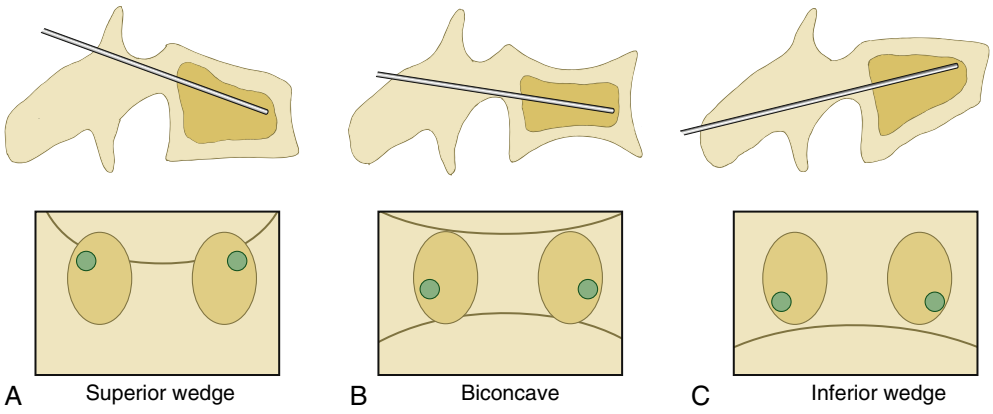


Fig. 19.11. Pedicle entry points and trajectories. **A,** Superior end plate compressions should be approached by directing the cannula toward the inferior end plate in the lateral view. **B,** Biconcave fracture cannulation should take place in the center of the vertebral body. **C,** Inferior compression fractures will require more of a cephalad cannula trajectory.

KYPHOPLASTY TECHNIQUE PEARLS

- Once the osteo introducer tip is ventral to the posterior cortex of the vertebral body, the bone drill is used (see Fig. 19.3 C).
- Inflate the bone tamp in small increments (i.e., 0.25 or 0.5 cc) to create a cavity with possible fracture reduction.
- Do not increase the total volume more than 4 cc when using the 10- and 15-mm bone tamps or more than 6 cc with the 20-mm inflatable bone tamps.
- Stop inflation if the balloon reaches its maximal volume, the pressure reaches 400 psi without decay, or there is cortical wall contact.

References

1. Kallmes DF, Jensen ME. Percutaneous vertebroplasty. *Radiology*. 2003;229:27–36.
2. Wardlaw D, Cummings SR, Van Meirhaeghe J, et al. Efficacy and safety of balloon kyphoplasty compared with non-surgical care for vertebral compression fracture (FREE): a randomised controlled trial. *Lancet*. 2009;373(9668):1016–1024.

CHAPTER 20

Thoracic Interlaminar Epidural Steroid Injection: Paramedian Approach

Michael B. Furman, Frank J.E. Falco, Jimmy M. Henry, and Akil S. Benjamin

Thoracic interlaminar epidural steroid injections are indicated more commonly for radiculopathy caused by a disc protrusion or stenosis of the central canal, intervertebral foramen, or lateral recess. These injections can also be used less commonly for the treatment of radiculopathy as a result of degenerative disc disease, compression fractures, acute herpes zoster, or postherpetic neuralgia.

Thoracic interlaminar epidural steroid injections are typically performed using a paramedian approach. As a result of the significant cephalocaudad and oblique angulation of the overlapping thoracic spinous processes, it is difficult to perform a median (midline) technique, particularly at the mid to upper thoracic levels. The paramedian approach in the thoracic spine allows the physician to "work around" and thus avoid the spinous processes when placing the needle tip in the interlaminar space.

A spinal needle can be used as a marker with the tip in contact with the superior lamina of the targeted interlaminar space in the anteroposterior (AP) view as long as the laminar bone is visible. The thoracic interlaminar epidural injection is performed with the "marker" so that there is no mistaking the level of injection when maneuvering the fluoroscope from the AP view to the caudally tilted trajectory view. The epidural needle is placed with the use of a paramedian trajectory view using fluoroscopic imaging and confirming the position and depth of the needle tip via the AP, lateral, and contralateral oblique (CLO) views.

For thoracic interlaminar epidural injections, advancing the epidural needle in the lateral or CLO view provides a safe approach into the epidural space, which is not offered by traditional AP only views. The CLO view enables visualization of the angle of the interlaminar space that is otherwise not evident with the AP or lateral view (see Chapter 3). This technique identifies the interlaminar space by optimizing the visualization of the laminae that border the space. The epidural needle is advanced through the space and beyond the ventral interlaminar line (VILL) to engage the ligamentum flavum. The epidural space is then identified after the use of a loss-of-resistance technique with air, saline, or air and saline, or the hanging drop technique. The use of saline is preferred to an air only technique to avoid a seizure or cord compression from an inadvertent subarachnoid injection of air.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 20.1)

The injection level is confirmed with AP view.

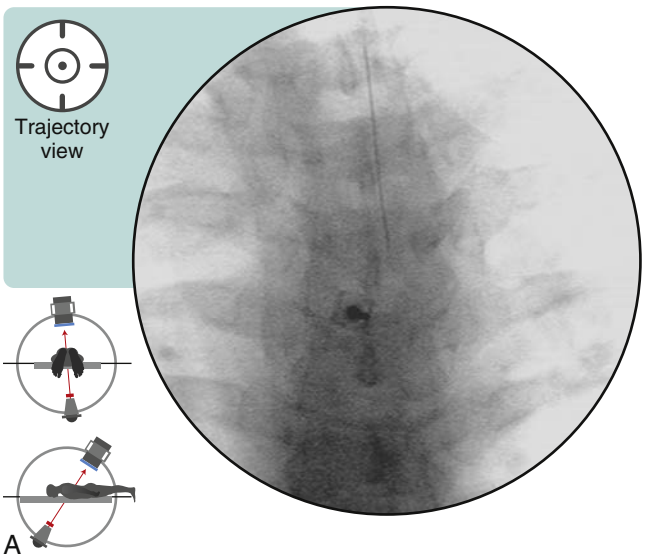
The fluoroscope is then tilted cephalad or caudad to maximize the interlaminar space and allow for needle placement between the overlapping laminae and spinous processes.

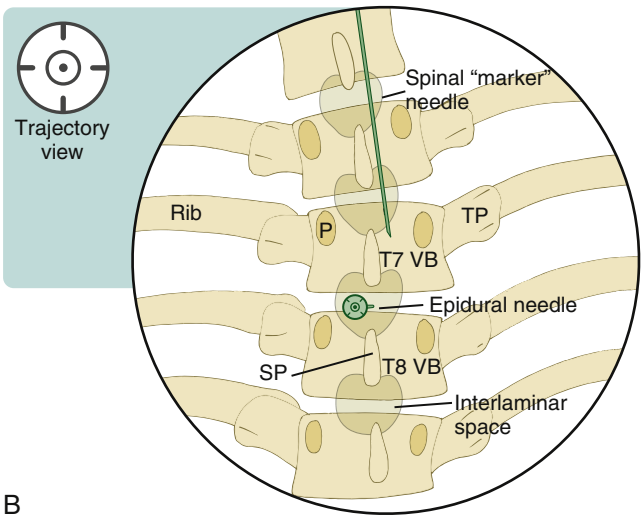
The fluoroscope is then obliqued approximately 5 degrees toward the more symptomatic side (or either side for symmetric pain).

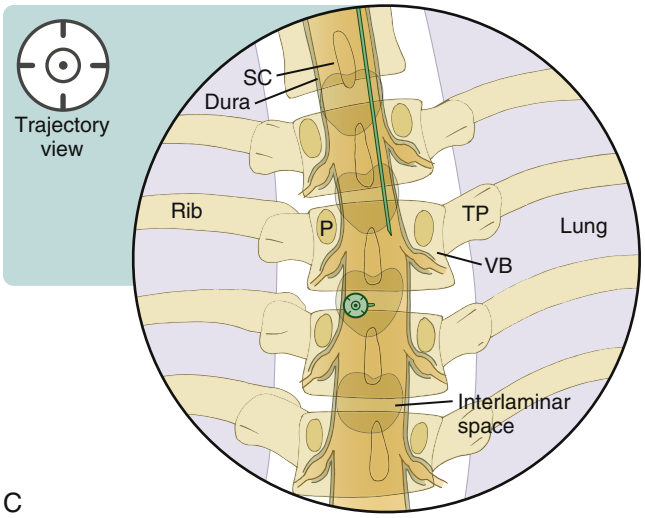
The needle is placed parallel to the fluoroscopic beam with the use of this trajectory approach.

Notes on Positioning in the Trajectory View

- With this approach, the needle is not "walked off" of the lamina. Rather, the needle is advanced safely and efficiently using multiplanar imaging until it reaches the VILL in the CLO view or the spinolaminar line in the lateral view.
- The needle tip is directed as close as possible to the midline to avoid the epidural veins.







The needle should not be advanced too far ventrally in this view. We recommend observing the safety considerations demonstrated in other views. There are no consistent radiolucent safety considerations in this trajectory view.

Fig. 20.1. A, Fluoroscopic image of a trajectory view with the epidural needle positioned at the thoracic interlaminar space along with the spinal needle marker. Left paramedian approach, T7-T8. Note that the image intensifier has been caudally tilted and that the epidural needle enters parallel to the fluoroscopic beam. Also note that the C-arm tilt angle makes the spinal needle used to *mark* the T7 level appear to come from the top of the screen. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

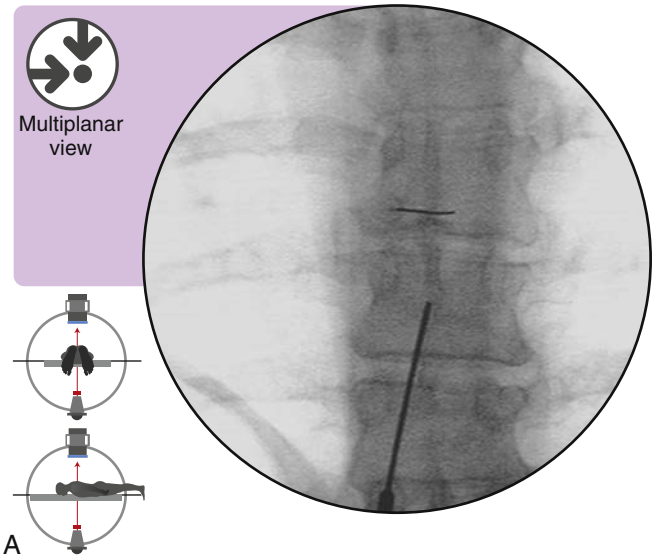
Optimal Needle Position in Multiplanar Imaging

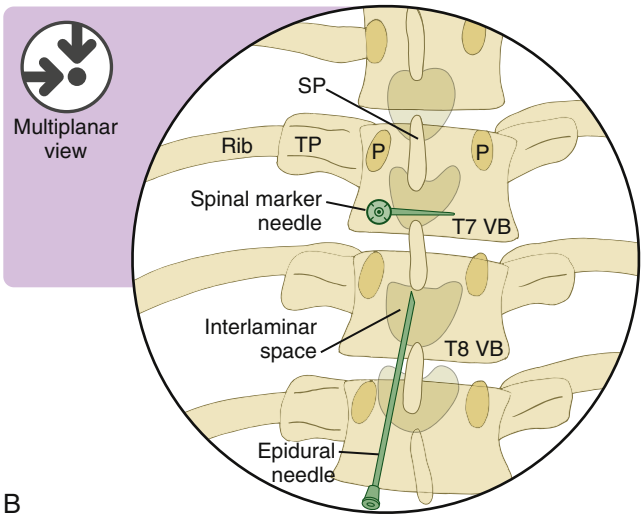
For multiplanar imaging, use the AP, CLO, and lateral views.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 20.2)

After the needle is placed in the trajectory view, oblique and tilt the C-arm back to a "true" AP view.

- Use the AP view to confirm that the needle is near the midline.





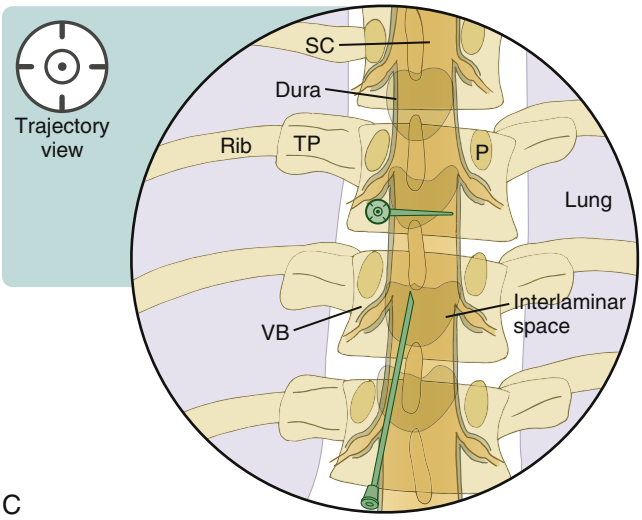


Fig. 20.2. A, Fluoroscopic anteroposterior (AP) view with the upper marker needle and lower ideal epidural needle position for a T7-T8 interlaminar epidural with a left paramedian approach. Note with the "true" AP view, the fluoroscopic beam is almost parallel to the spinal needle used to mark the T7 level. In addition, the epidural needle has a much shallower "trajectory" orientation. **B,** Radiopaque structures, AP view. **C,** Radiolucent structures, AP view. (Note that this is not the safety view for this procedure; these images are used to emphasize the location of the spinal cord from an AP perspective.)

- The needle should not be advanced too far ventrally in this view. We recommend observing the safety considerations demonstrated in other views. There are no consistent radiolucent safety considerations in this AP view.
- The AP view is utilized to confirm that the needle tip is paramedian. Needle advancement takes place in the CLO and/or lateral views.

Notes on Optimal Needle Positioning

- Most of the needle advancement takes place with the use of the lateral or CLO fluoroscopy views to visualize the association among the needle, interlaminar space, and VILL in the CLO view and/or the spinolaminar line in the lateral view.
- The loss-of-resistance technique is employed with further needle advancement as the needle reaches the VILL in the CLO view or the spinolaminar line in the lateral view.
- Alternate between the AP, lateral, and CLO fluoroscopy views during advancement to ensure that the needle tip remains paramedian and to track needle depth.

OPTIMAL NEEDLE POSITIONING IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 20.3)

Because it is often challenging to visualize the interlaminar space in the AP view, the C-arm can also be positioned in a CLO position to optimize the laminae's elliptical shape. (If the needle tip lies perfectly in the midline, the oblique view may be ipsilateral or contralateral.) The needle is then directed into the interlaminar space, which is located between the elliptical-appearing laminar structures and advanced to the VILL (see Chapter 3).

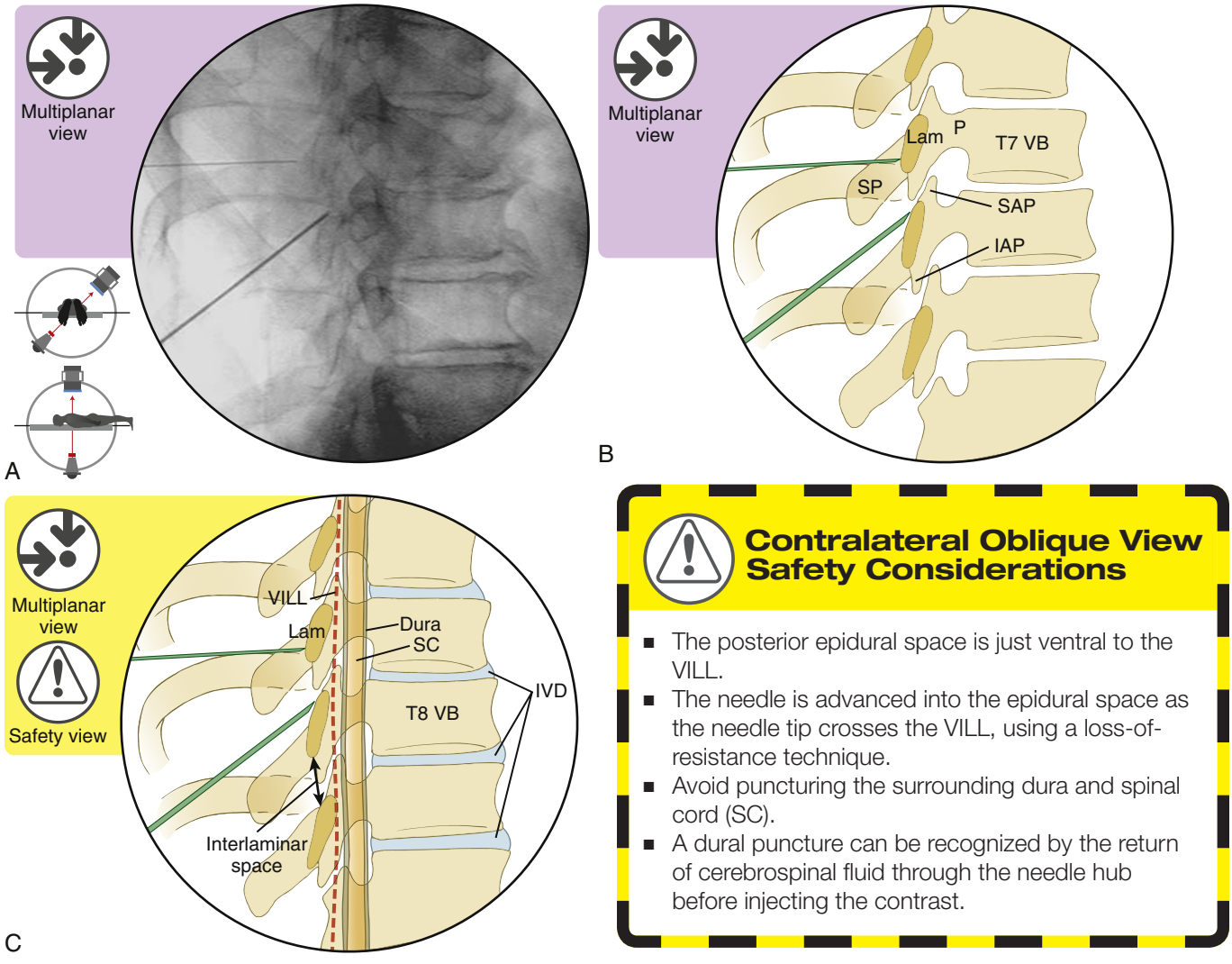


Fig. 20.3. A, Fluoroscopic contralateral oblique view with the needle in contact with the subjacent lamina. The tip has not yet reached the final position, which will be ventral to the ventral interlaminar line (VILL). Note that the epidural needle is approaching parallel to the laminae (Lam). **B,** Radiopaque structures, contralateral oblique view. **C,** Radiolucent structures, contralateral oblique view. The final needle tip position should be just ventral to the VILL. Fig. 20.6 demonstrates contrast at the ideal final needle tip position. Compare with the 3D reconstruction computed tomography image in Fig. 3.22C.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 20.4)

When the needle is approaching the midline target according to both the trajectory and AP views, a lateral image is obtained.

The C-arm should be oriented to obtain a "true" lateral view (see Chapter 3). This is important when assessing the association of the needle tip to the proximity of the spinolaminar line.

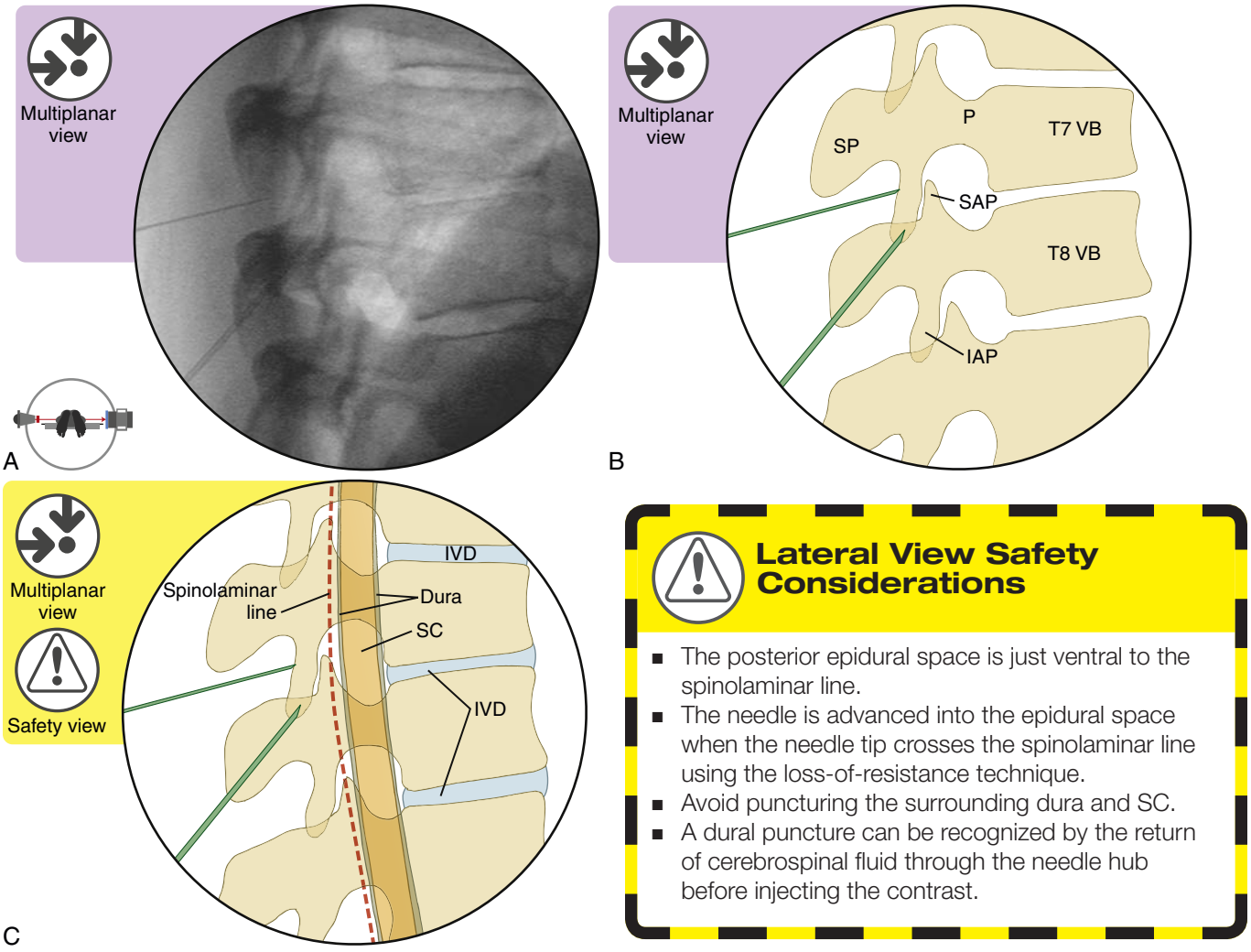


Fig. 20.4. A, Fluoroscopic lateral view with the upper *marker* needle and lower ideal epidural needle approaching the final target. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view. The final needle tip position should be just ventral to the spinolaminar line. Fig. 20.7 demonstrates contrast at the ideal final needle tip position.

Optimal Imaging (Figs. 20.5 to 20.7)

See Table 12.1 for further description of potential flow pattern.

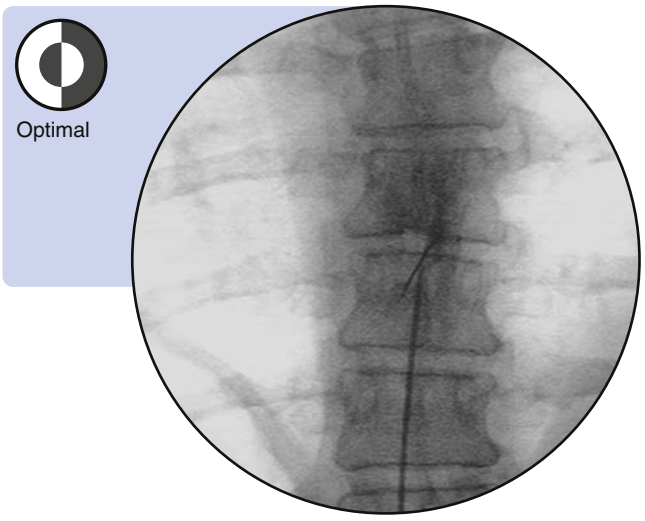


Fig. 20.5. Anteroposterior fluoroscopic image of a thoracic interlaminar epidural steroid injection with 2 cc of contrast medium. Right paramedian approach, T7-T8.

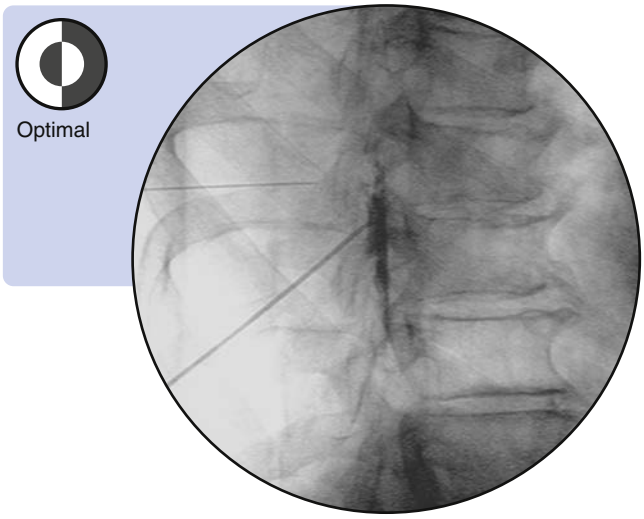


Fig. 20.6. Contralateral oblique fluoroscopic image of a thoracic interlaminar epidural steroid injection with 2 cc of contrast medium.

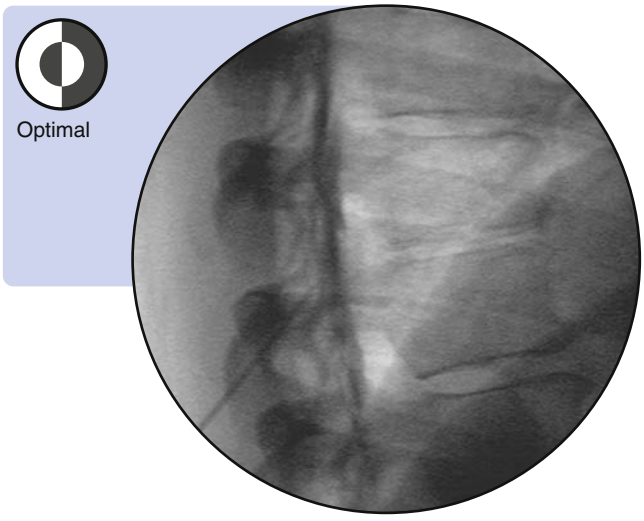


Fig. 20.7. Lateral fluoroscopic image of a thoracic interlaminar epidural steroid injection with 2 cc of contrast medium.

Optimal Image

Anteroposterior

- The majority of contrast should flow to the symptomatic side with the paramedian technique.
- Epidural fat gives an irregular appearance.
- Contrast should spread cephalad and caudad for one to two levels, although this can be limited in the presence of central stenosis.

Lateral

- Contrast should flow immediately ventral to the spinolaminar line.

Contralateral Oblique

- Contrast should flow immediately ventral to the VILL.

Suggested Readings

Buttermann GR. The effect of spinal steroid injections for degenerative disc disease. *Spine J*. 2004;4(5):495–505.

Forrest JB. Management of chronic dorsal root pain with epidural steroid. *Can Anaesth Soc J*. 1978;25(3):218–225.

Forrest JB. The response to epidural steroid injections in chronic dorsal root pain. *Can Anaesth Soc J*. 1980;27(1):40–46.

Hernandez R, Lopez F. Assessment of pain intensity in patients with diabetic polyneuropathy treated with peridural 2% lidocaine methylprednisolone acetate vs peridural 2% lidocaine. *Anestesia en Mexico*. 1999;11:65–69.

Kikurchi A, Kotani N, Sato T, Takamura K, Sakai I, Matsuki A. Comparative therapeutic evaluation of intrathecal versus epidural methylprednisolone for long-term analgesia in patients with intractable postherpetic neuralgia. *Reg Anesth Pain Med*. 1999;24:287–293.

Landers MH, Dreyfus P, Bogduk N. On the geometry of fluoroscopy views for cervical interlaminar epidural injections. *Pain Medicine*. 2012;13(1):58–65.

O'Connor RC, Andary MT, Russo RB, DeLano M. Thoracic radiculopathy. *Phys Med Rehabil Clin N Am*. 2002;13(3):623–644. viii.

Prather H, Watson JO, Gilula LA. Nonoperative management of osteoporotic vertebral compression fractures. *Injury*. 2007;38(Suppl 3):S40–S48.

CHAPTER 21

Thoracic Transforaminal Epidural Steroid Injection: Infraneural Approach

Justin J. Petrolla, Christopher Bednarek, and Michael B. Furman

Although thoracic epidural injections are uncommon, they are indicated for radicular symptoms with or without axial pain, resulting from thoracic spine pathology. The transforaminal approach offers medication delivery to specific thoracic spine locations.

Several approaches can be used for a transforaminal injection. In this chapter, we will describe the infraneural approach, which has also been called the preganglionic or retrodiscal approach. With this approach, the needle will stay "low in the hole" (i.e., in the lower third of the foramen).

Using the approach described here, the needle is placed with the use of a trajectory view and advanced using multiplanar imaging, with an emphasis placed on safety. The orientation of the zygapophysial joints and the articulation with the ribs makes this injection more challenging. One must also be aware of the lung fields at all times when performing thoracic transforaminal epidural injections.

Note that the initial trajectory is quite similar to that used for thoracic discography, as described in Chapter 24.

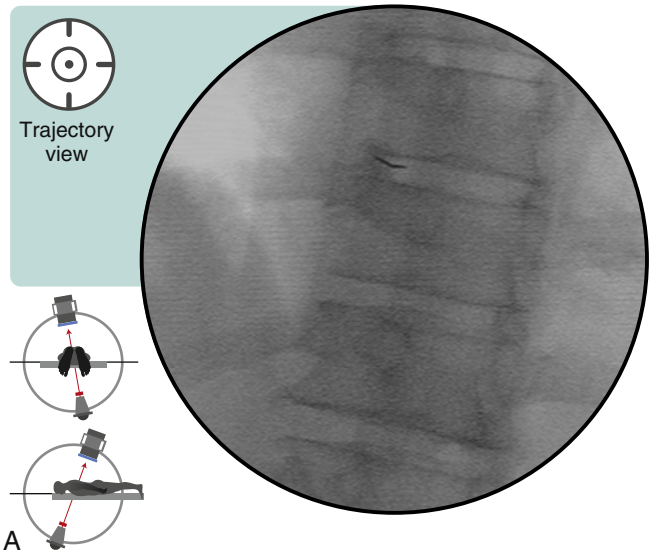
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

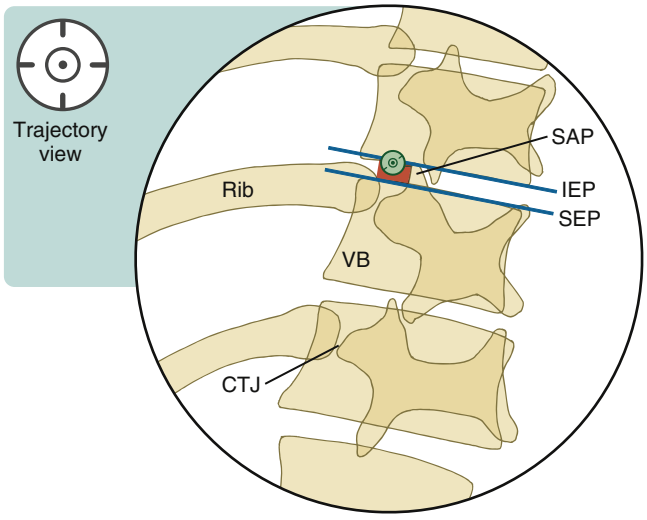
- **Confirm the level** (with the anteroposterior view).
- **Tilt the fluoroscope** caudad or cephalad to optimize end plate visualization of the targeted segment.
- **Oblique the fluoroscope** ipsilaterally (Fig. 21.1).
- The C-arm is then obliqued toward the symptomatic side ideally with the superior articular process (SAP) bisecting the end plates.
- Adjust the degree of angulation for each individual intervertebral disc level.
- The needle's initial entry is in the lower third of the foramen or "low in the hole."
- **The trajectory is similar to that used in thoracic disc access** (Chapter 24). There is a target "box" (shown in red) formed by the superior end plate inferiorly, the inferior end plate superiorly, the SAP medially, and the rib laterally.
- Place the needle parallel to the fluoroscopic beam.

Notes on Positioning in the Trajectory View

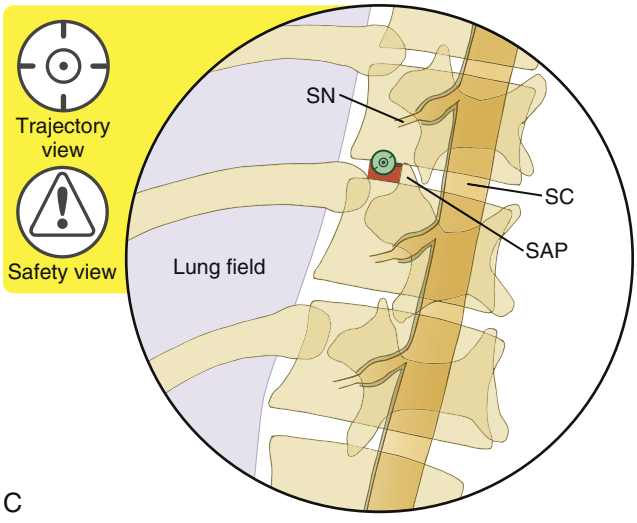
Maintain the needle in the lower third or "low in the hole." Do not venture off the trajectory to avoid contact with the lung field, which is located lateral to the target trajectory.



A



B



C

Trajectory View Safety Considerations

- Avoid contacting the spinal nerve (SN).
  - Remain inferior in the foramen, toward the base of SAP (i.e., "low in the hole")
- Avoid the dura.
  - While advancing the needle, do not go too far medial or lateral. Remain immediately lateral to the junction of the superior end plate and SAP.
  - Avoid puncturing the lungs by staying on the trajectory path and not straying ventrally or laterally.

Fig. 21.1. A, Fluoroscopic image of a trajectory view with the needle in position. **B,** Radiopaque structures, trajectory view. Target "box" is shown in red. **C,** Radiolucent structures (lung fields are approximated), trajectory view. Target "box" is shown in red.

Optimal Needle Position in Multiplanar Imaging

Also see Chapter 13 (lumbar transforaminal epidural steroid injection) for needle localization/trouble shooting diagrams.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 21.2)

- As the target is approached, drive the needle tip slightly superior to avoid disc entry.

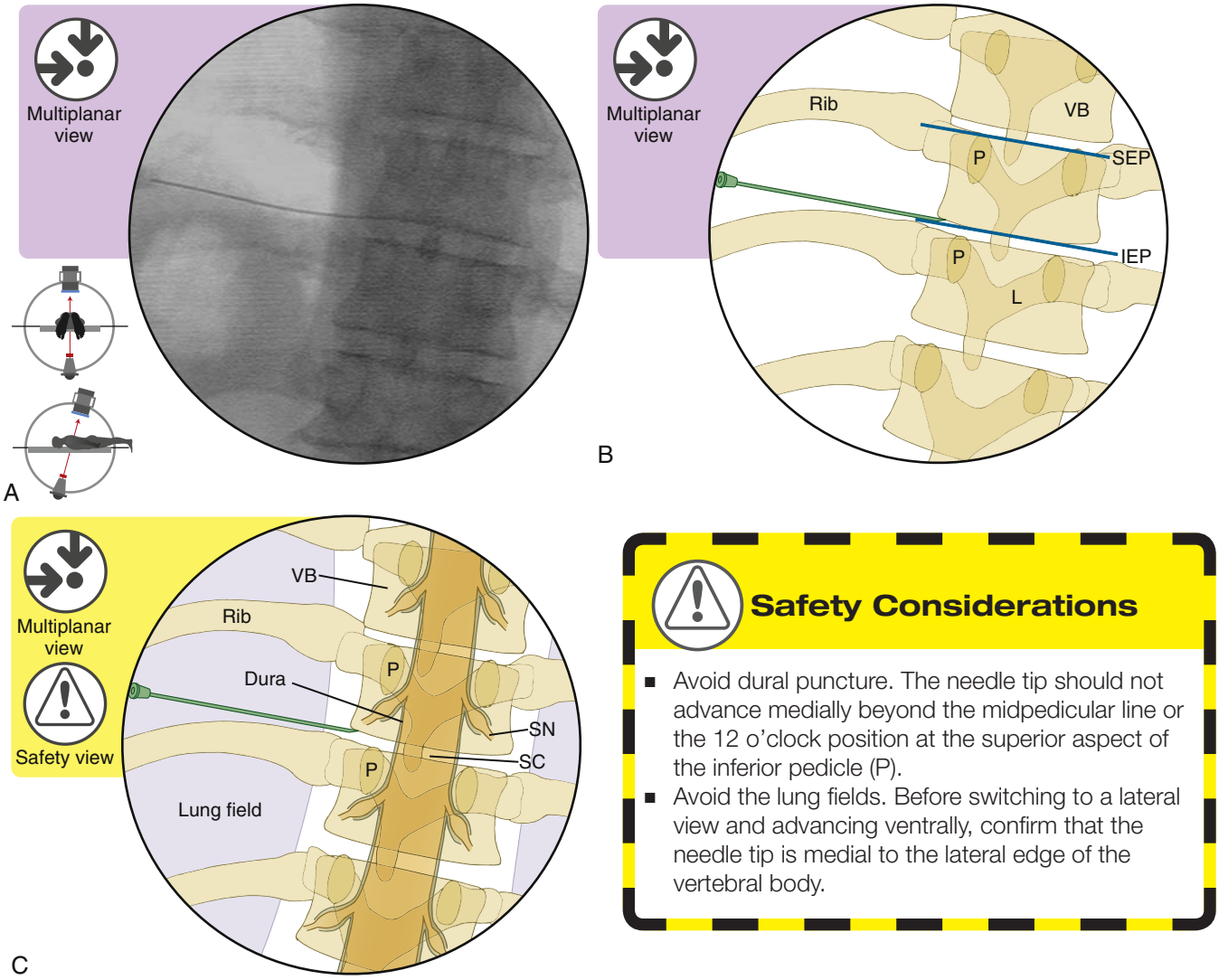
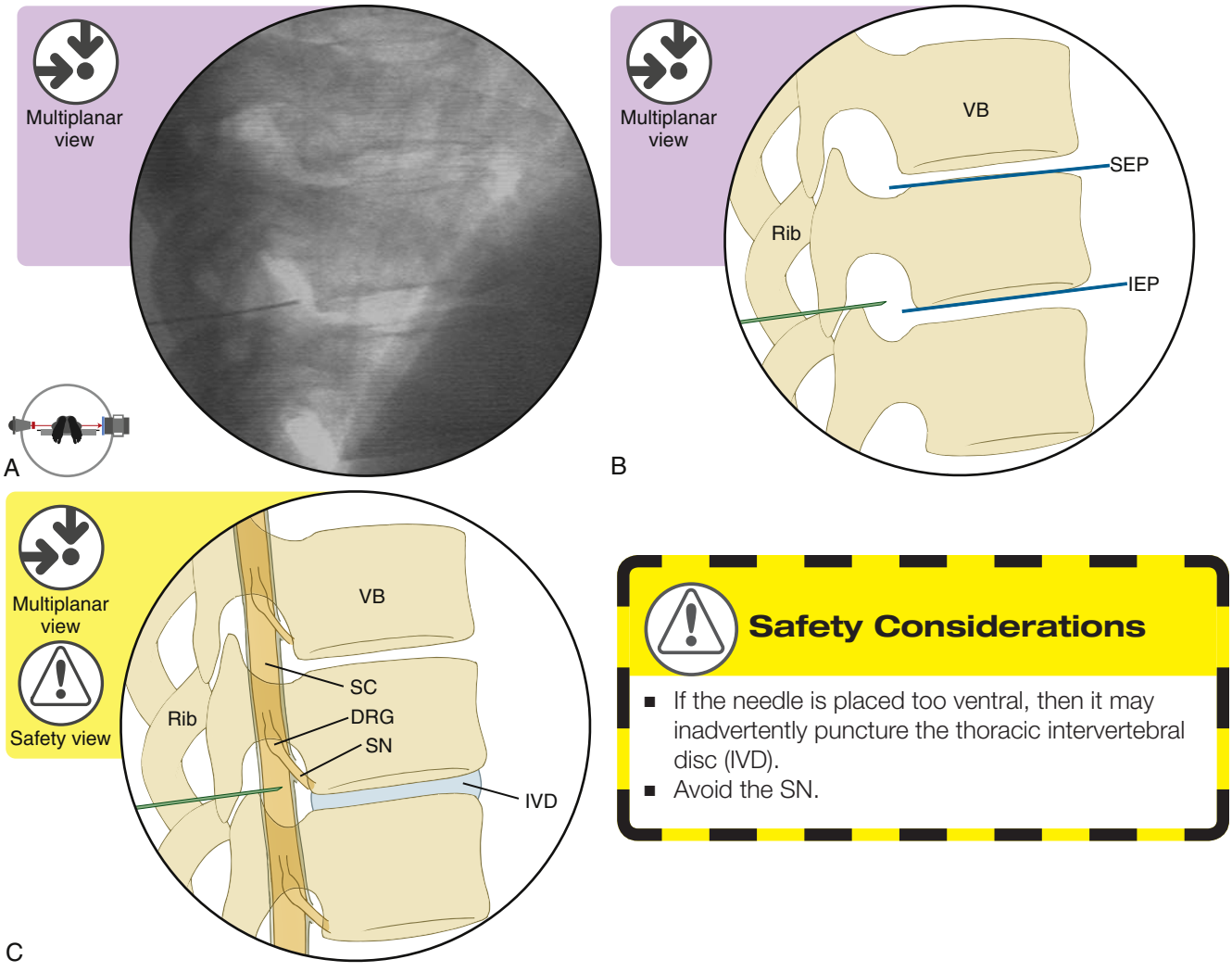


Fig. 21.2. A, Fluoroscopic anteroposterior view with the ideal needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures (lung fields are approximated), anteroposterior view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 21.3)

Notes on the Optimal Needle Position

After the needle tip has attained the optimal position in both trajectory and anteroposterior views, obtain a lateral image. The lateral view is the safety view for ventral depth.



Safety Considerations

- If the needle is placed too ventral, then it may inadvertently puncture the thoracic intervertebral disc (IVD).
- Avoid the SN.

Fig. 21.3. A, Fluoroscopic lateral view with the ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images (Fig. 21.4)

Ideal flow should outline the SN, nerve root sheath, and epidural space. Contrast often flows to the posterior disc/nerve interface.

The infraneural approach is beneficial for getting injectate along the nerve as it travels inferiorly past the centrally herniated disc.

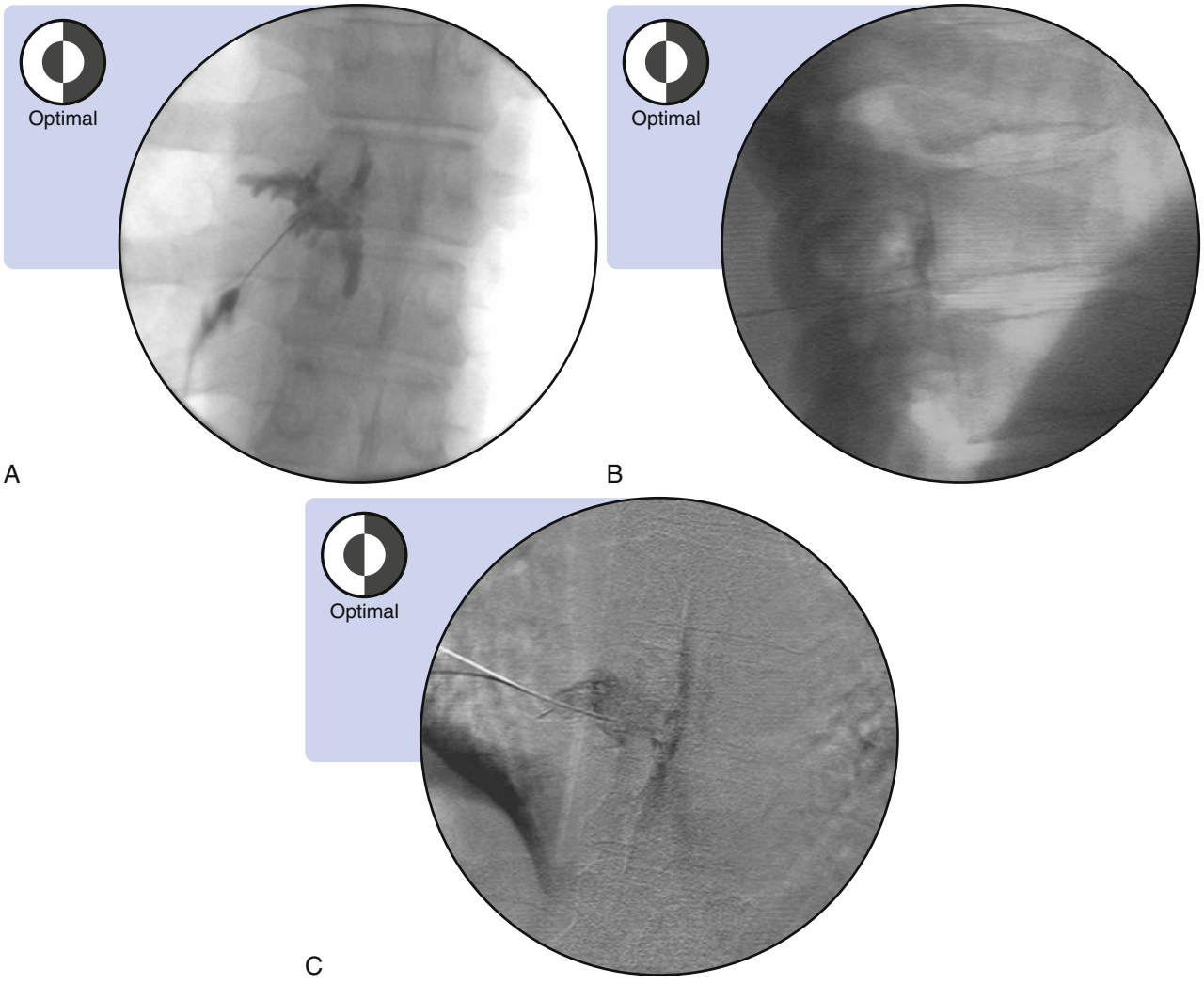


Fig. 21.4. A, Anteroposterior fluoroscopic images of a thoracic transforaminal injection with 1.5 cc of contrast medium extending both superiorly and inferiorly. **B,** Lateral fluoroscopic image of a thoracic transforaminal injection with 1.5 cc of contrast medium extending both superiorly and inferiorly. **C,** Anteroposterior digital subtraction image of a thoracic transforaminal injection with 2 cc of contrast medium.

Suggested Reading

Bogduk N, ed. *Practice Guidelines for Spinal Diagnostic and Treatment Procedures*. 2nd ed. San Francisco: International Spine Intervention Society; 2013:265–282.

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CHAPTER 22

Thoracic Zygapophysial (Facet) Joint Procedures

Thoracic zygapophysial (facet) joint procedures are indicated for the treatment and diagnosis of axial thoracic (i.e., midback) pain that typically originates from the zygapophysial joint sprains, contusions, or osteoarthritis. Thoracic facet joint pain is not as common as cervical or lumbar facet joint pain partly because of the lack of mobility of the thoracic spine compared with the cervical and lumbar spine segments. All of the thoracic facet joint procedures are performed with a posterior approach.

There is no needle trajectory view for entering the thoracic zygapophysial joint, but otherwise, the thoracic medial branch diagnostic blocks and radiofrequency neurotomy have unique trajectory views as outlined in their respective chapters.

The labeling and location of the thoracic medial branch nerves are demonstrated in Chapter 22D. The nerves travel around the intertransverse ligament and continue medially toward the cephalad neuroforamina where they finally join the somatic nerve. As a result, the medial branch nerves are not labeled for the transverse process that they cross but rather for their originating somatic nerves. For example, the T8 medial branch crosses the superolateral edge of the T9 transverse process as illustrated in Chapter 22D. Each thoracic zygapophysial joint receives innervation from two medial branch nerves: from the exiting somatic nerve at the level of the thoracic zygapophysial joint and from the one above it (see illustrations in Chapter 22D). For example, the T8-T9 zygapophysial joint receives innervation from the T7 and T8 medial branch nerves.

The C8 medial branch has a course similar to that of the upper thoracic medial branches (personal communication, Frank Willard, PhD, anatomist), so we recommend treating the C8 medial branch with techniques similar to those used for thoracic level procedures.

The T11 and T12 medial branch nerves have a course similar to that of the lumbar levels, so we recommend using landmarks and techniques similar to those used for lumbar medial branch nerve interventions.

Thoracic zygapophysial joint pain must first be confirmed through controlled diagnostic medial branch nerve blocks (see Chapter 22B) before considering radiofrequency neurolysis (see Chapter 22C). Two adjacent medial branch nerves must be denervated to reduce the thoracic zygapophysial joint pain. For example, the T5 and T6 medial branch nerves must be denervated to treat pain that originates from the T6-T7 zygapophysial joint.

The needle trajectory for C8 and T1-T0 medial branch injections is more sagittal compared with thoracic radiofrequency, where the needle is placed more obliquely (medial to lateral) to position the needle parallel to the nerve. The needle and electrode tip position and depth are confirmed with anteroposterior and lateral views. Ipsilateral oblique views are recommended for the T11 and T12 medial branch nerves because their locations are similar to those of the lumbar medial branch nerves.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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CHAPTER 22A

Thoracic Zygapophysial Joint Intraarticular Injection—Posterior Approach: Fluoroscopic Guidance

Frank J.E. Falco and Michael B. Furman

Thoracic zygapophysial (facet) joint injections are performed by entering the zygapophysial joint at the inferior aspect of the joint. A substantial caudad tilt of the fluoroscope is required to accomplish a trajectory view of the joint space because of the steep coronal orientation of the thoracic zygapophysial joints. Unfortunately, the torso prevents the fluoroscope from reaching the required degree of caudad tilt for a trajectory view.

The reliable approach described herein can be used to routinely allow for the placement of a spinal needle into the thoracic zygapophysial joint. This technique has been previously described in the literature using a posterior approach with anteroposterior (AP) visualization. With AP visualization, the needle tip can be maintained along the midpedicular line, which corresponds with the midline of the zygapophysial joints and prevents the straying of the needle medially or laterally to avoid the neural and pulmonary structures. Contralateral oblique imaging provides for the visualization of the posteroinferior joint space, thereby allowing for needle placement into the joint. Using a bent needle tip (Chapter 2) is helpful for navigating into the joint and overcoming osseous obstacles in a degenerative joint.

The needle entry site into the skin is confirmed with AP visualization at the pedicle one vertebral segment below the designated zygapophysial joint. For example, the entry site in most individuals for a left T8-T9 zygapophysial joint injection is the 6 o'clock position of the left T10 pedicle, and the target site for entry into the Z-joint is the 12 o'clock position of the T9 pedicle (Fig. 22A.1, B). The rationale for the skin entry and Z-joint target sites is to approximate the "trajectory angle" of the needle tip into the posteroinferior aspect of the joint space because of its near coronal orientation and inability to obtain a trajectory view with fluoroscopy. The needle tip is advanced with fluoroscopy and makes contact with the lamina at the base of the superior articular process of the target Z-joint. The needle tip trajectory is then adjusted and advanced into the Z-joint in the contralateral oblique view.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View

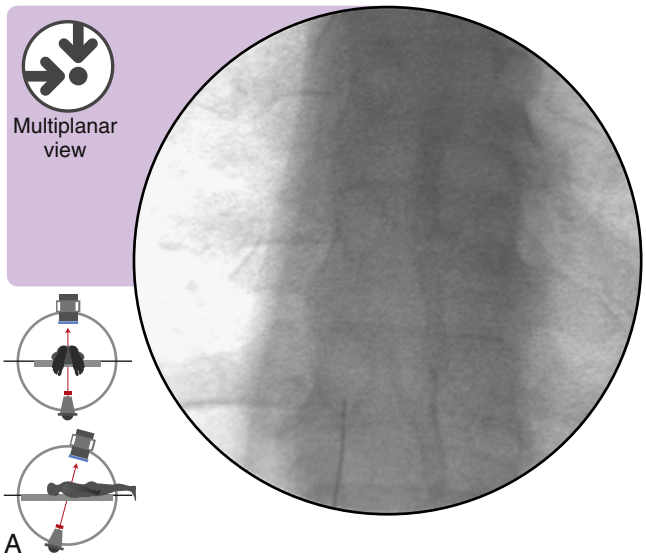
No trajectory view is available for entering the thoracic zygapophysial joint.

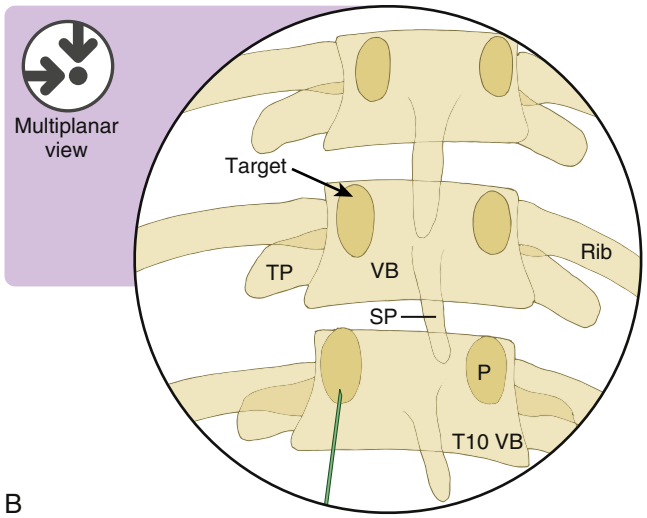
Optimal Needle Position in Multiplanar Imaging

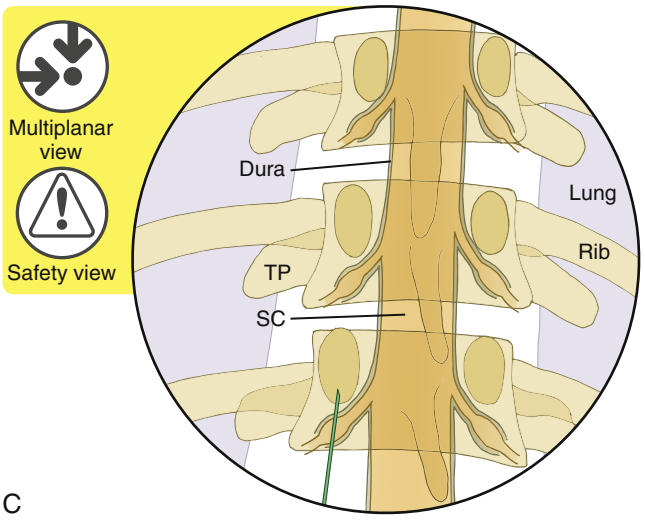
OPTIMAL NEEDLE POSITIONING IN THE AP VIEW (FIG. 22A.1)

Notes on Positioning in the AP View

- This image is used to emphasize the locations of the spinal cord and various pulmonary structures from an AP view. This view helps to maintain the needle in the midpedicular line, which is necessary to align the needle with the center of the posterior and inferior aspects of the thoracic zygapophysial joint.
- The needle is advanced at an angle of approximately 60 degrees in association to the thoracic spine.
- In larger individuals, the skin entry point is more caudad to account for the larger body mass that the needle must pass through to reach the targeted zygapophysial joint. However, the same 60-degree angle is maintained as the needle is advanced to the joint.
- In smaller individuals, the skin entry point is more cephalad to account for a smaller body mass. Again, the same 60-degree angle is used for needle advancement.







Safety Considerations for the AP View

- This view should only be used to assess the mediolateral and superoinferior needle tip positioning.
- Avoid the lateral lung.
- Avoid the medial neural structures.

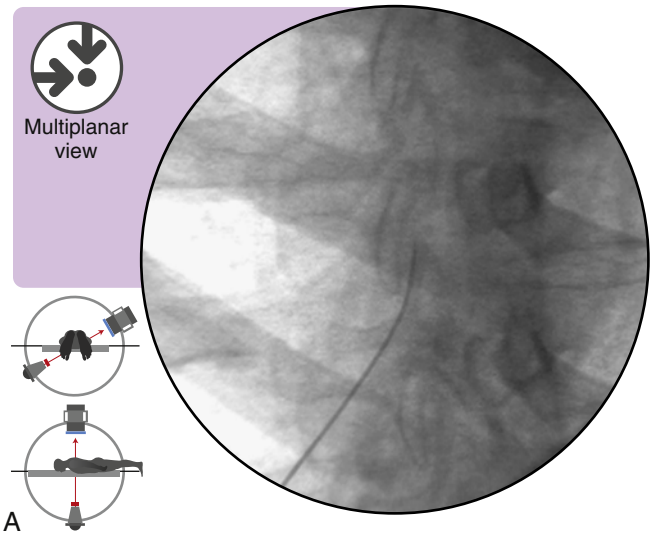
Fig. 22A.1. A, Fluoroscopic AP view with the needle skin entry position identified at the left T10 pedicle and aligned with the midpedicular line. **B,** Radiopaque structures, AP view. **C,** Radiolucent structures, AP view.

OPTIMAL NEEDLE POSITIONING IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 22A.2)

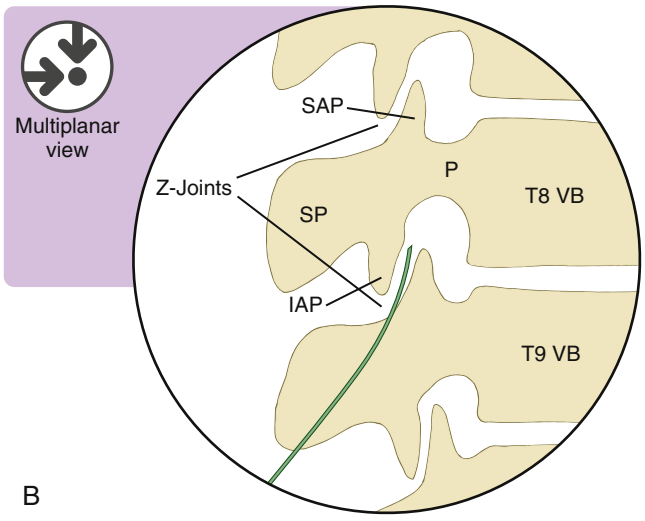
- A contralateral oblique image is obtained when the needle tip in the AP view approaches the vertebral pedicle associated with the superior articular process of the targeted zygapophysial joint (e.g., the T9 vertebral pedicle for the T8-T9 joint).
- The C-arm should be positioned in a contralateral oblique orientation to obtain a clear view of the zygapophysial joint. This is important for assessing the association of the needle to the proximity of the posterior and inferior aspects of the zygapophysial joint space.

Notes on the Contralateral Oblique View Needle Positioning

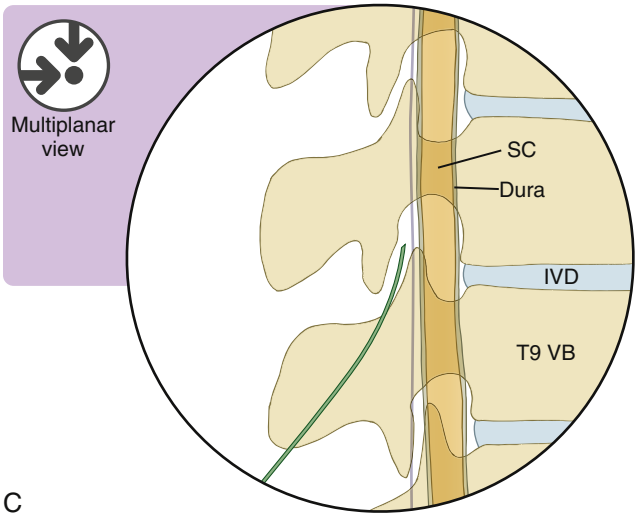
- Alternating AP and contralateral oblique fluoroscopic views are obtained during advancement to ensure that the needle tip remains within the center of the joint space and to track needle depth so that the tip does not go too far anteriorly.
- Most of the needle advancement into the joint takes place in the contralateral oblique view after contacting the periosteum (at the target point), which positions the needle tip inferior to the zygapophysial joint. The contralateral view visualizes the association between the needle tip and joint space as it is advanced into the joint.



A



B



C

Safety Considerations for the Contralateral Oblique View

- Exercise caution when advancing the needle. Be sure that it does not appear to have advanced too far anteriorly beyond the zygapophysial joints. A needle that appears too anterior may have actually glanced off the midpedicular line too laterally (potentially leading to a pneumothorax) or too medially (potentially leading to a dural or spinal cord puncture).
- The AP view keeps the needle within the midpedicular line and on course to enter the joint space while advancing the needle.

Fig. 22A.2. A, Fluoroscopic contralateral oblique view with the ideal needle position within the left T8-T9 zygapophysial joint. **B,** Radiopaque structures, contralateral oblique view. **C,** Radiolucent structures, contralateral oblique view.

Optimal Images (Figs. 22A.3 and 22A.4)

Optimal Images

AP:

- The contrast should flow within the zygapophysial joint space.
- Only a minimal amount of contrast should be injected in the joint to allow space for the injectate solution.

Contralateral Oblique:

- To maintain the specificity, the contrast should stay within the confines of the zygapophysial joint and not flow into the epidural space. Excessive distention of the zygapophysial joint may lead to extravasation into the epidural space.

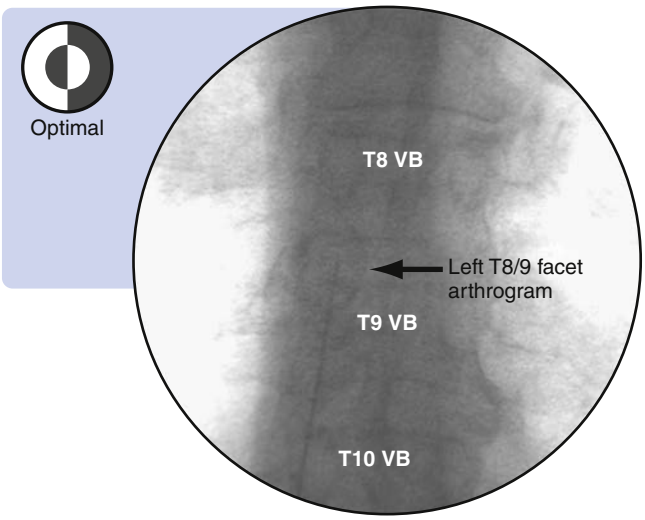


Fig. 22A.3. AP fluoroscopic image of a thoracic zygapophysial joint arthrogram, left T8-T9 zygapophysial joint.

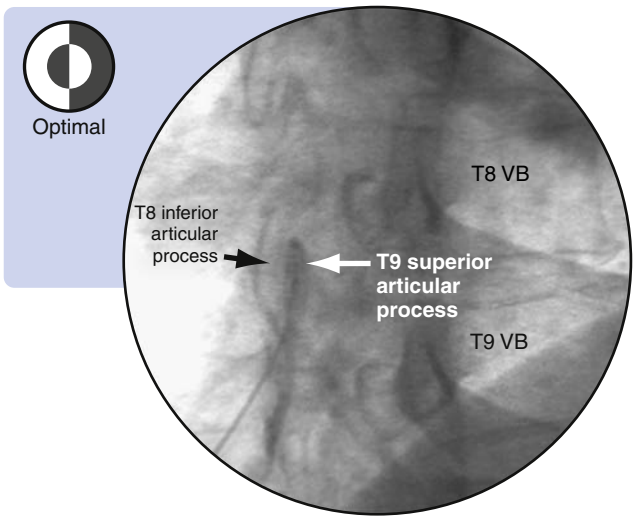


Fig. 22A.4. Contralateral oblique fluoroscopic image of a thoracic zygapophysial joint arthrogram, left T8-T9 zygapophysial joint.

Video 22A.1. Digital subtraction video demonstrating optimal contrast filling of a thoracic Z-Joint. Notice the arthrogram's circular outline.

Suggested Readings

Dreyfuss P, Tibiletti C, Dreyer SJ. *Spine (Phila Pa 1976)*. 1994;19(7):807–811.

Dreyfuss P, Tibiletti C, Dreyer S, Sobel J. Thoracic zygapophysial pain: a review and description of an intraarticular block technique. *Pain Digest*. 1994;4:46–54.

Fortin JD, McKee MJ. Thoracic zygapophysial blocks: bent needle technique. *Pain Physician*. 2003;6(4):513–516.

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CHAPTER 22B

Thoracic Zygapophysial Joint Nerve (Medial Branch) Injection—Posterior Approach: Fluoroscopic Guidance

Frank J.E. Falco, Brian D. Steinmetz, and Michael B. Furman

The courses of the C8 and thoracic medial branch nerves are described in the introduction of Chapter 22 and demonstrated in Chapter 22D.

For C8 and thoracic medial branch blocks, the needle tip is placed at the superolateral edge of the transverse process, where each medial branch nerve is located. The C8 and T1-T10 medial branch nerves are injected in this manner, whereas the T11 and T12 medial branch nerves are injected using similar landmarks that are used when injecting the lumbar medial branch nerves.

The spinal needle is placed using a fluoroscopic anteroposterior (AP) view, which is the trajectory view for injecting the medial branch nerves. The needle tip position and depth are confirmed with AP and lateral views. Ipsilateral oblique views are recommended for the T11 and T12 medial branch nerves because their locations are similar to the lumbar medial branch nerves.

The needle trajectory for C8 and T1-T10 medial branch injections is more sagittal, in contrast to the thoracic radiofrequency (RF). The spinal needle is placed using a fluoroscopic AP view, which is the trajectory view for injecting the medial branch nerves. The needle tip position and depth are confirmed with AP and lateral views. Ipsilateral oblique views are recommended for the T11 and T12 medial branch nerves because their locations are similar to the lumbar medial branch nerves.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 22B.1)

Optimal Needle Position in Multiplanar Imaging

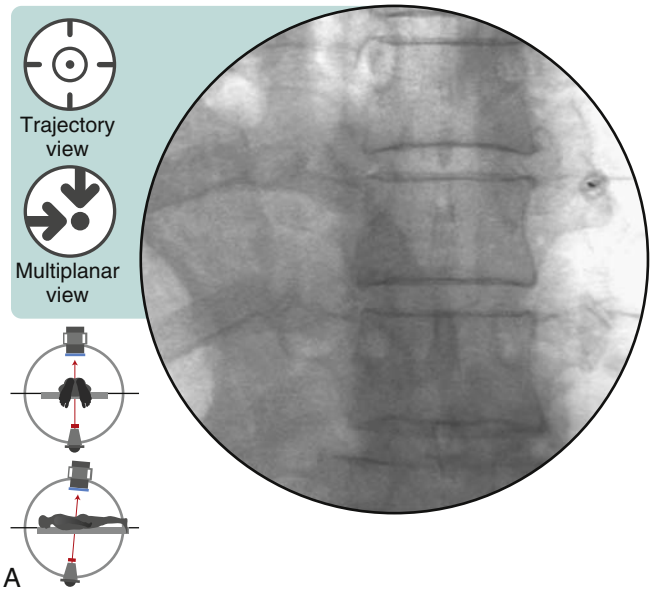
The Trajectory View (AP) Is Also a Multiplanar View

The injection level is confirmed with the AP view.

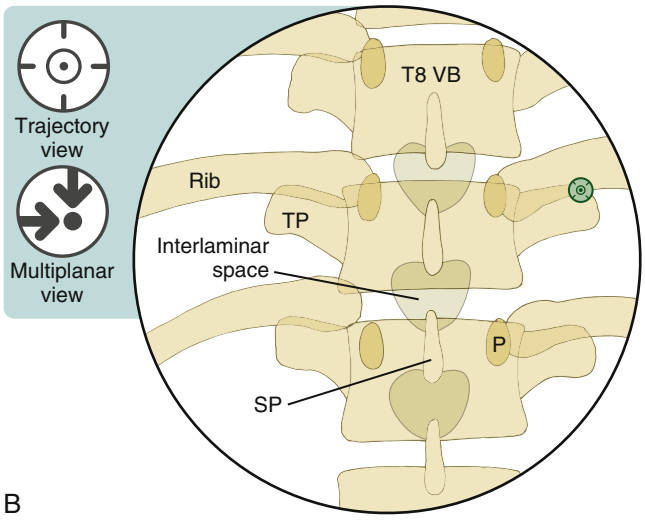
The needle is placed parallel to and advanced within the fluoroscopic beam to the superolateral edge of the transverse process until the needle tip contacts the periosteum.

Notes on Positioning in the Trajectory View

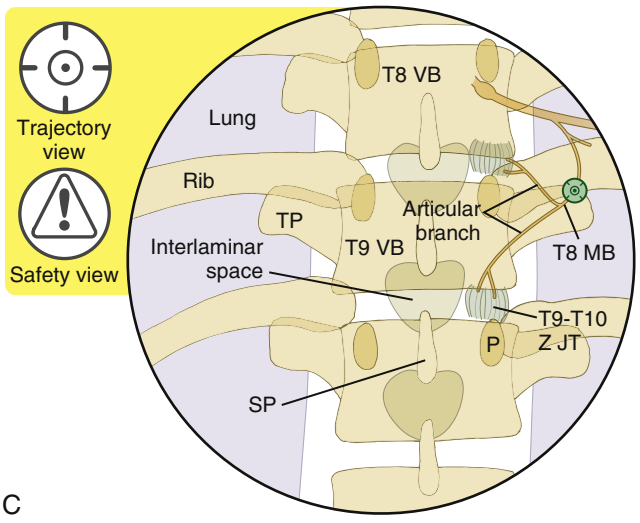
- With this approach, the needle tip is posterior to the superolateral edge of the transverse process over which the targeted medial branch nerve passes. The needle is not "walked off" of the edge of the transverse process. Rather, the needle is safely advanced by alternating between AP and lateral fluoroscopic views until the tip contacts the superolateral edge of the transverse process.
- A different spinal needle can be used as a marker to identify the injection level.



A



B



C

Anteroposterior View Safety Considerations

- This view should only be used to assess the mediolateral and superoinferior needle tip positioning; it should not be used for any substantial needle advancement.
- It is important to keep the needle in line with the superolateral edge of the transverse process to avoid the lung that is anterior to the transverse process.

Fig. 22B.1. A, Fluoroscopic image of the trajectory view with the needle position aligned with the right T9 transverse process and the right T8 thoracic medial branch nerve. **B,** Radiopaque structures, trajectory view, right T9 transverse process and right T8 thoracic medial branch nerve. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

Notes on Optimal Needle Positioning

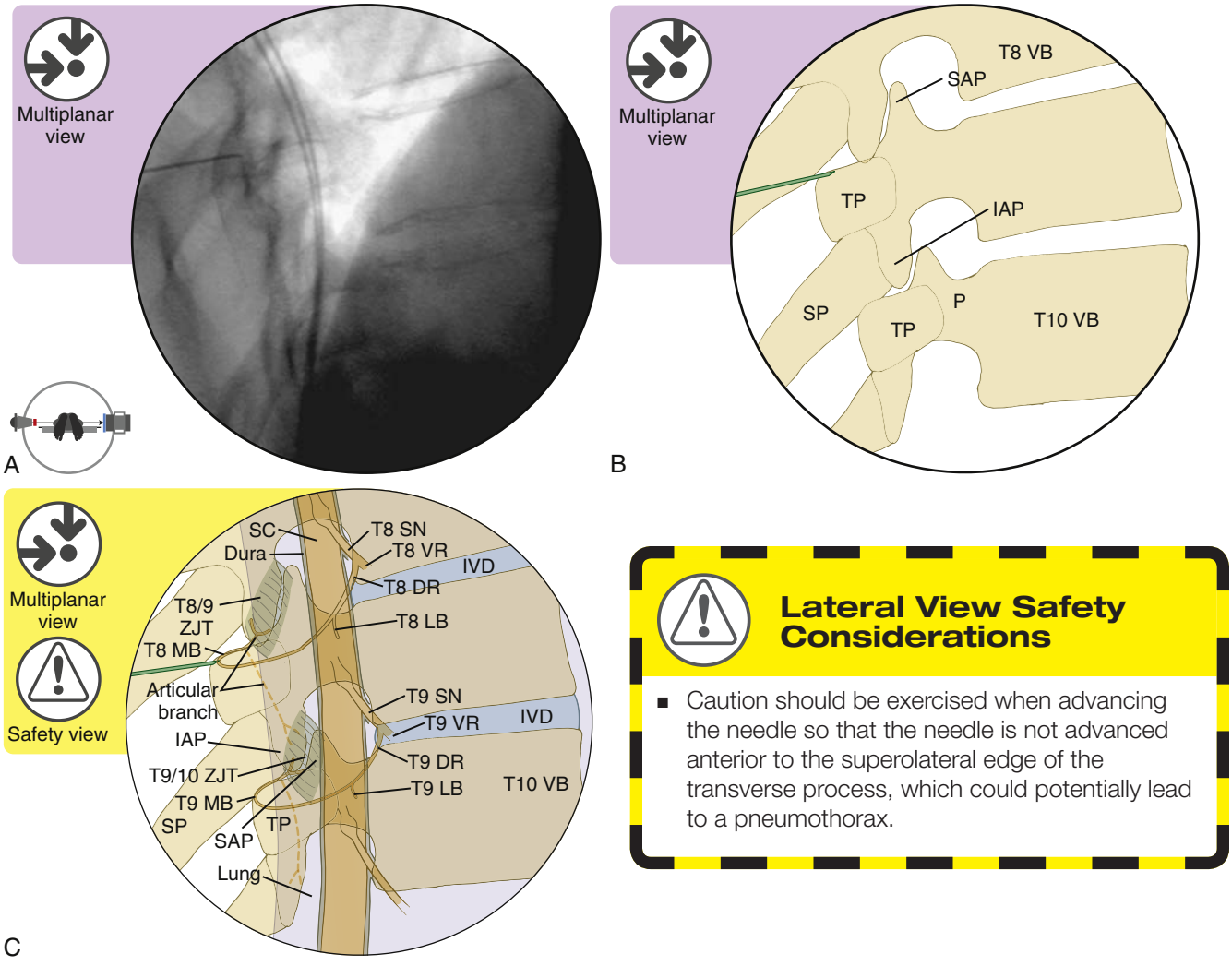
- Alternating anteroposterior and lateral fluoroscopic views are obtained during advancement to ensure that the needle tip remains within the superolateral edge of the transverse process and to track the needle depth.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 22B.2)

When the needle is approaching the superolateral edge of the transverse process in the trajectory/AP view, obtain a lateral view.

Confirm a true lateral by having the ribs line up (see Chapter 3).

The C-arm should be oriented to obtain a "true" lateral (see Chapter 3). This is important for assessing the relationship of the needle to the proximity of the transverse process.



Lateral View Safety Considerations

- Caution should be exercised when advancing the needle so that the needle is not advanced anterior to the superolateral edge of the transverse process, which could potentially lead to a pneumothorax.

Fig. 22B.2. A, Fluoroscopic lateral view with the ideal needle position, right T9 transverse process and right T8 thoracic medial branch nerve. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images (Figs. 22B.3 and 22B.4)

Optimal Images

- The labeling and location of the thoracic medial branch nerves are covered in Chapter 22D.
- The contrast is injected with continuous fluoroscopy in the AP and lateral views after the needle is positioned at the superolateral edge of the transverse process to confirm that there is no vascular uptake of contrast material.

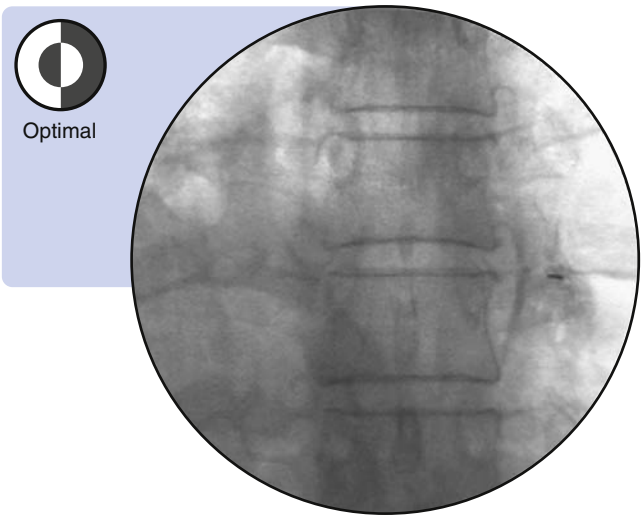


Fig. 22B.3. Anteroposterior fluoroscopic image of the right T9 transverse process and the right T8 thoracic medial branch nerve with 0.5 cc of contrast medium.

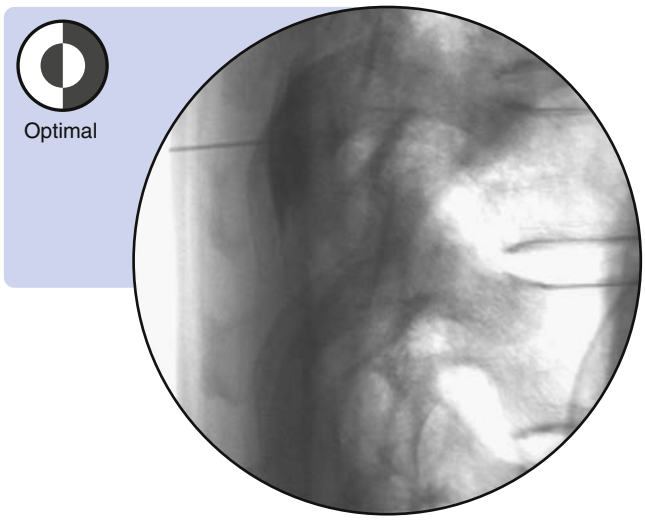


Fig. 22B.4. Lateral fluoroscopic image of the right T9 transverse process and the right T8 thoracic medial branch nerve with 0.5 cc of contrast medium.

AP

- The contrast should cover the superolateral edge of the transverse process.

LATERAL

- The contrast should flow dorsal to the transverse process.

Suggested Readings

Atluri S, Datta S, Falco FJ, Lee M. Systematic review of diagnostic utility and therapeutic effectiveness of thoracic facet joint interventions. *Pain Physician*. 2008;11(5):611–629.

Boswell MV, Colson J, Sehgal N, Dunbar EE, Epter R. A systematic review of therapeutic facet joint interventions in chronic spinal pain. *Pain Physician*. 2007;10(1):229–253.

Chua WH, Bogduk N. The surgical anatomy of the thoracic facet denervation. *Acta Neurochir (Wien).* 1995;136(3–4):140–144.

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CHAPTER 22C

Thoracic Zygapophysial Joint Nerve (Medial Branch) Radiofrequency Neurotomy—Posterior Approach: Fluoroscopic Guidance

Frank J.E. Falco, Brian D. Steinmetz, and Michael B. Furman

The courses of the C8 and thoracic medial branch nerves are described in the introduction of Chapter 22 and demonstrated in Chapter 22D. A thoracic medial branch nerve radiofrequency (RF) neurolysis is indicated for the treatment of axial thoracic (i.e., midback) pain that typically originates from zygapophysial (i.e., facet) joint sprains, contusions, or osteoarthritis. This procedure is performed via a posterior approach. The RF electrode tip is placed at the superolateral edge of the transverse process in an oblique manner so that the tip bisects the superolateral edge.

Thoracic zygapophysial joint pain relief must first be confirmed through positive controlled diagnostic medial branch nerve blocks (see Chapter 22B) before considering RF neurolysis. Two medial branch nerves must be addressed to denervate a thoracic zygapophysial joint. For example, the T5 and T6 medial branch nerves must be denervated to treat pain that originates from the T6-T7 zygapophysial joint.

This chapter will focus on the RF electrode placement for C8 and thoracic medial branch neurolysis. As discussed in Chapter 22B and demonstrated in 22D, the medial branch nerve locations in association to the transverse process vary anatomically, depending on the thoracic level.

The variability of the medial branch nerve location is greatest in the midthoracic spine region (i.e., T4-T8) (Fig. 22D.1). An injection of a phenol solution has been used to create medial branch chemical neurolysis.[2] Although there is a lack of supportive evidence in the literature, phenol injection has been used either alone or in combination with RF to denervate medial branch nerves, especially those with variable location such as T4-T8. For C8 and T1-T10 RF, the electrode is placed more obliquely (medial to lateral) and more parallel to the nerve than the trajectory for thoracic medial branch injections. This facilitates a larger area for neurolysis. Ipsilateral oblique views are recommended for the T11 and T12 medial branch nerves because their locations are similar to those of the lumbar medial branch nerves.

The needle is placed with the use of a fluoroscopic trajectory view along the medial branch nerves, confirming the needle tip position and depth in the anteroposterior (AP) and lateral views prior to denervation. Ipsilateral oblique views are also recommended for the T11 and T12 medial branch nerves because their locations are similar to those of the lumbar medial branch nerves.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 22C.1)

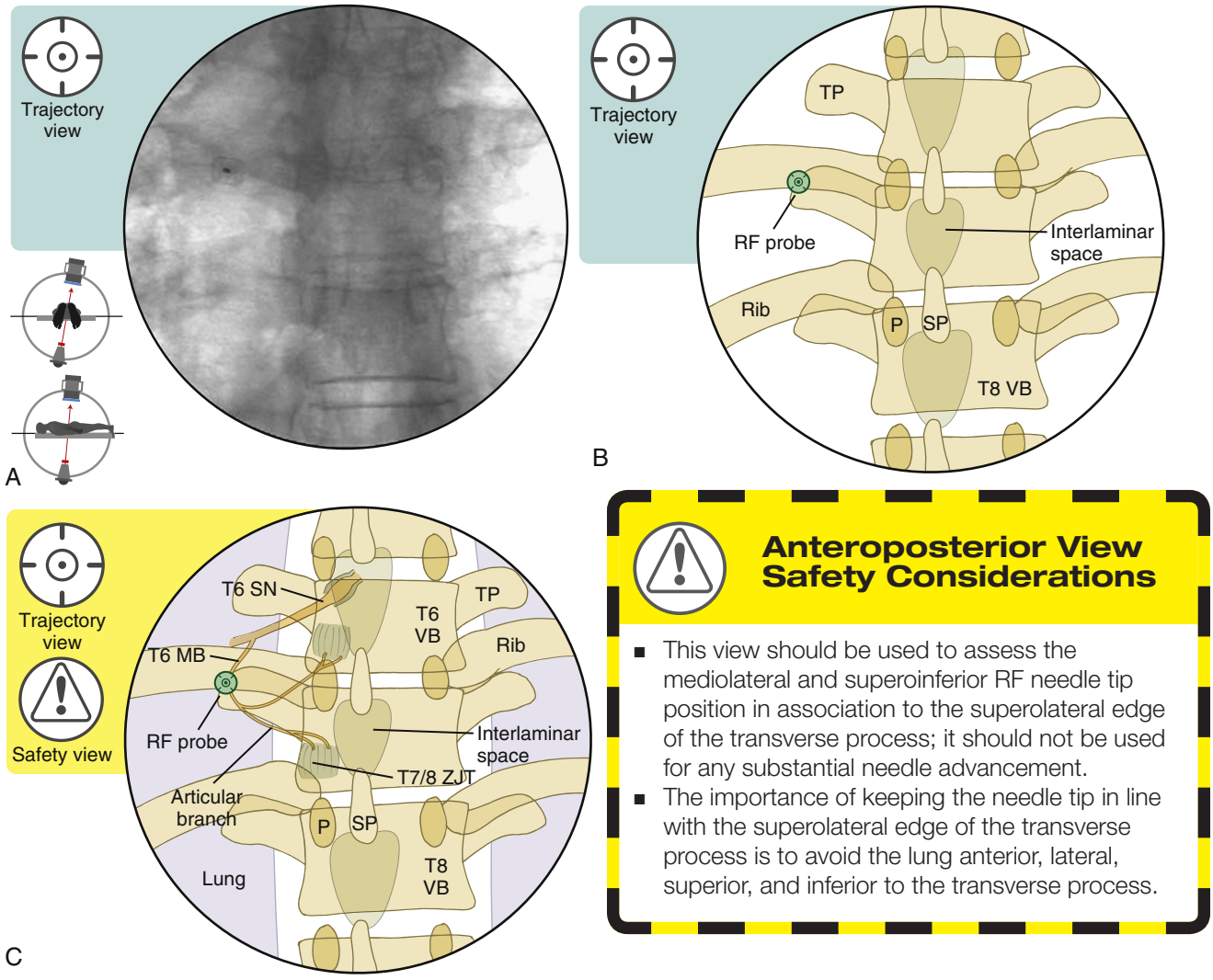
The injection level is confirmed using the AP view before obtaining the trajectory view (see Chapter 1).

The fluoroscope is then obliqued 10 degrees contralaterally and 10 degrees caudally from the AP view so that the RF electrode is positioned parallel to the course of the medial branch nerve.

The RF needle is placed parallel to the fluoroscopic beam with the use of this trajectory approach to target the superolateral edge of the transverse process.

Notes on Positioning in the Trajectory View

- The needle tip is safely advanced by alternating between AP and lateral views until it contacts the superolateral edge of the transverse process. The needle tip is then "walked off" just superior and lateral to the edge of the transverse process.
- With this medial to lateral approach, the needle tip is positioned obliquely at the superolateral edge of the transverse process along the medial branch nerve instead of perpendicular to the medial branch nerve, thereby providing a greater area for neurolysis.



Anteroposterior View Safety Considerations

- This view should be used to assess the mediolateral and superoinferior RF needle tip position in association to the superolateral edge of the transverse process; it should not be used for any substantial needle advancement.
- The importance of keeping the needle tip in line with the superolateral edge of the transverse process is to avoid the lung anterior, lateral, superior, and inferior to the transverse process.

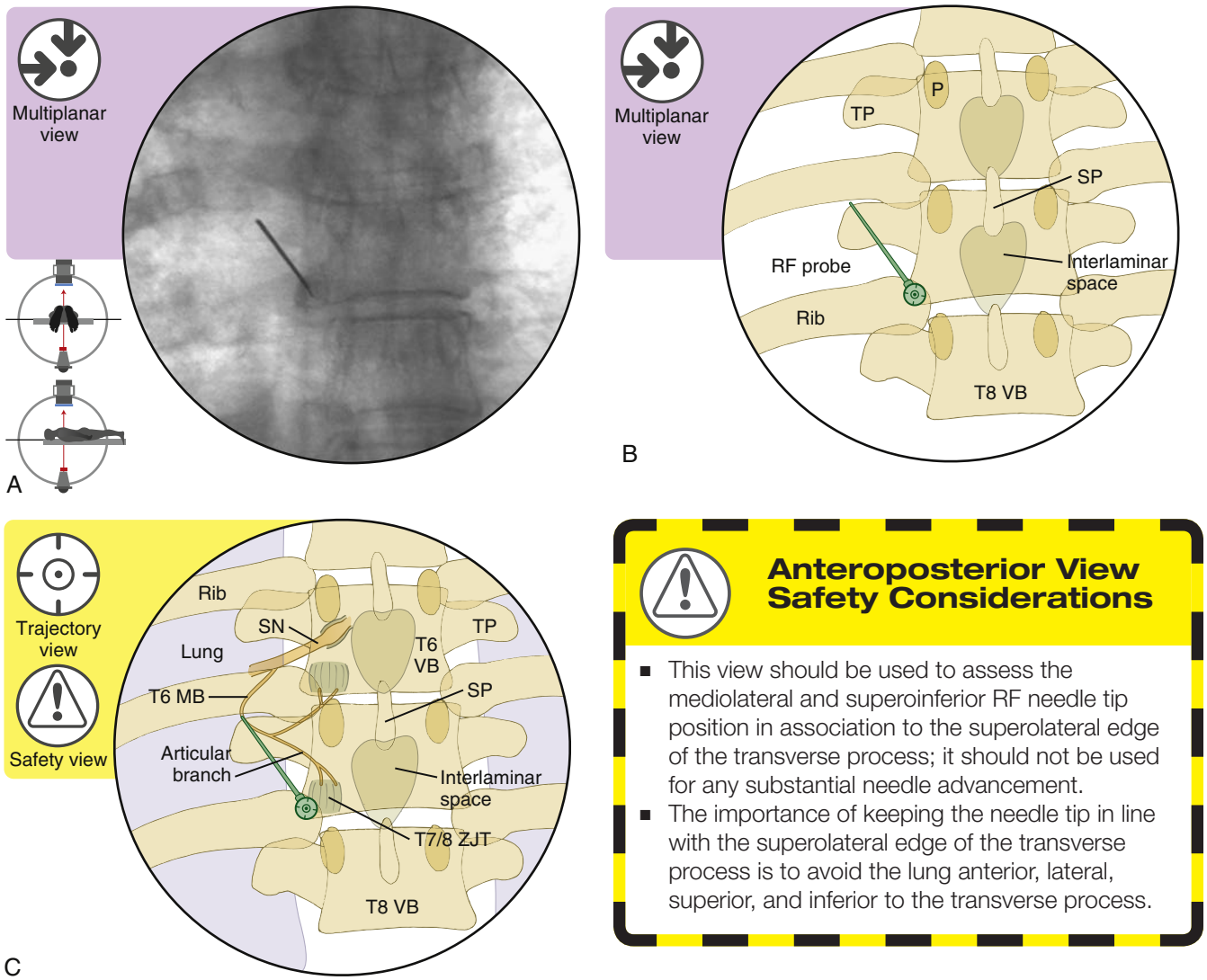
Fig. 22C.1. A, Fluoroscopic image of a trajectory view with the radiofrequency needle position aligned with the left T7 transverse process so that the tip bisects the superolateral edge of the transverse process. The radiofrequency electrode overlies the left T6 medial branch nerve. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

Optimal Needle Positioning in the Anteroposterior View (Fig. 22C.2)

When the RF needle is placed in the trajectory view, tilt the C-arm back to a "true" AP view.

There are typically no radiolucent structures that are safety considerations with this AP view, aside from advancing the needle too far ventrally. Please use the other views for needle advancement to best visualize the corresponding landmarks.



Anteroposterior View Safety Considerations

- This view should be used to assess the mediolateral and superoinferior RF needle tip position in association to the superolateral edge of the transverse process; it should not be used for any substantial needle advancement.
- The importance of keeping the needle tip in line with the superolateral edge of the transverse process is to avoid the lung anterior, lateral, superior, and inferior to the transverse process.

Fig. 22C.2. A, Fluoroscopic anteroposterior view with the ideal radiofrequency needle position. The radiofrequency electrode overlies the left T6 medial branch nerve. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 22C.3)

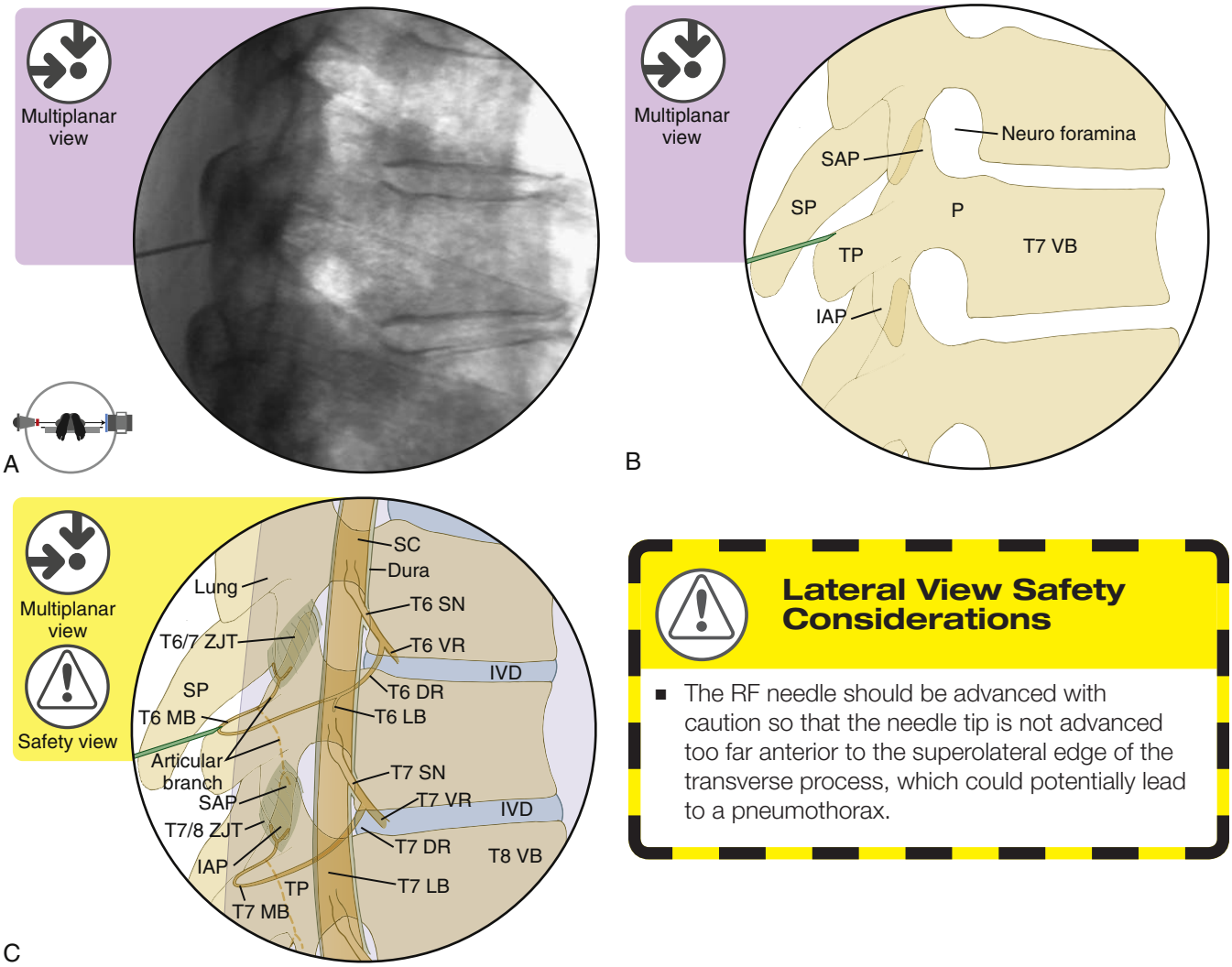
Confirm a "true" lateral view by having the ribs line up (see Chapter 3).

When the RF needle is approaching the superolateral edge of the transverse process according to both the trajectory and AP views, a lateral image is obtained.

The C-arm should be oriented to obtain a "true" lateral view (see Chapter 3). This is important when assessing the association of the RF needle to the proximity of the transverse process.

Notes on Optimal Needle Positioning

- Most of the RF needle advancement takes place with the use of the lateral fluoroscopy view to visualize the association between the needle and transverse process.
- Alternating AP and lateral fluoroscopic views are obtained during advancement to ensure that the needle tip remains within the superolateral edge of the transverse process and to track the needle depth.
- The needle tip is then "walked off" just superior and lateral to the edge of the transverse process along the medial branch nerve, placing the tip in the most optimal position for RF neurolysis.



Lateral View Safety Considerations

- The RF needle should be advanced with caution so that the needle tip is not advanced too far anterior to the superolateral edge of the transverse process, which could potentially lead to a pneumothorax.

Fig. 22C.3. A, Fluoroscopic lateral view with the ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images (See multiplanar Figs. 22C.2A and 22C.3A)

The labeling and location of the thoracic medial branch nerves are covered in Chapter 22D.

Optimal Imaging

Anteroposterior View:

- The optimal location of the RF electrode is within the confines of the superolateral edge of the transverse process and not too far medial or lateral.

Lateral View:

- The optimal location of the RF electrode is within the area superior to and along the transverse process and not too far ventral.

References

1. Chua WH, Bogduk N. The surgical anatomy of the thoracic facet denervation. *Acta Neurochir (Wien)*. 1995;136(3–4):140–144.
2. Weksler N, Klein M, Gurevitch B, et al. Phenol neurolysis for severe chronic nonmalignant pain: is the old also obsolete? *Pain Medicine*. 2007;8(4):332–337.

Suggested Readings

Atluri S, Datta S, Falco FJ, Lee M. Systematic review of diagnostic utility and therapeutic effectiveness of thoracic facet joint interventions. *Pain Physician*. 2008;11(5):611–629.

Boswell MV, Colson JD, Sehgal N, Dunbar EE, Epter R. A systematic review of therapeutic facet joint interventions in chronic spinal pain. *Pain Physician*. 2007;10(1):229–253.

Dreyfuss P, Kaplan M, Dreyer S. Zygapophysial joint injection techniques in the spinal axis. In: Lennard T, ed. *Pain Procedures in Clinical Practice*. 2nd ed. Philadelphia, PA: Hanley & Belfus; 2000:276–308.

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CHAPTER 22D

Thoracic Zygapophysial Joint Innervation: Anatomy Diagrams

Brian D. Steinmetz and Luis Baez-Cabrera

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

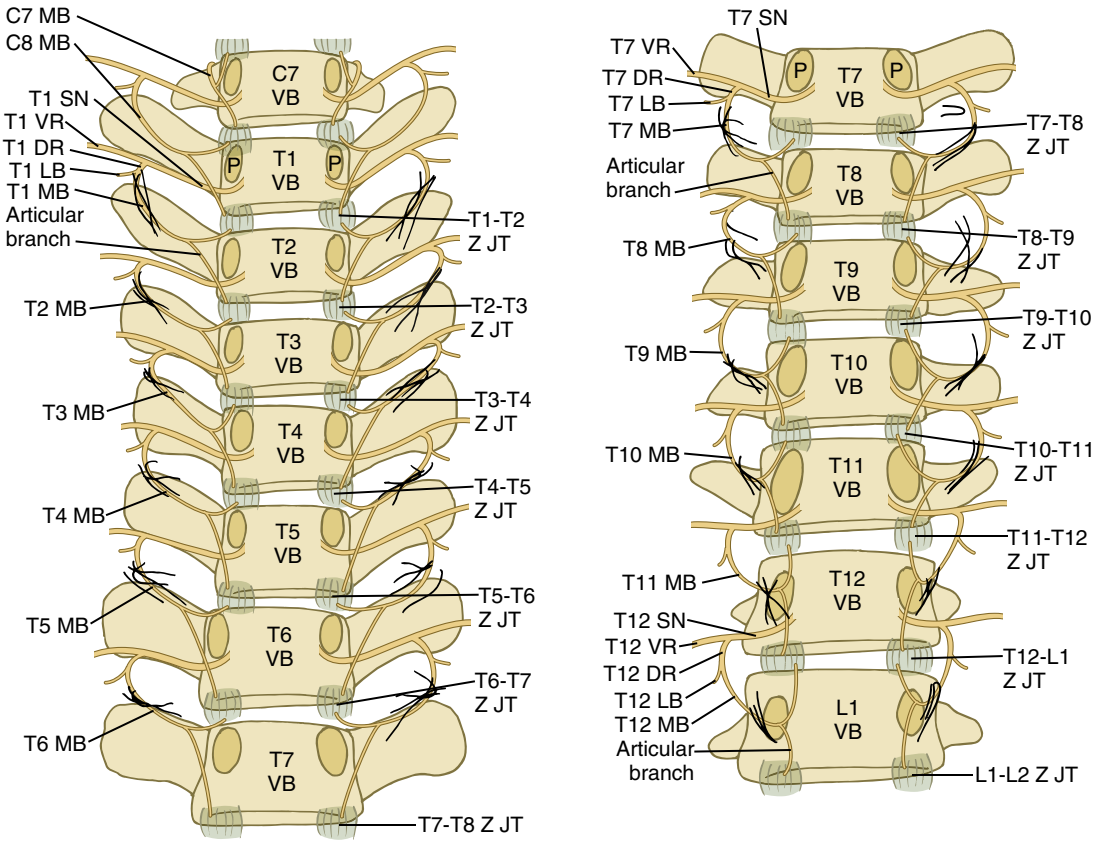

Fig. 22D.1. Anatomic location of the C8 and thoracic medial branch nerves. The location of the medial branch nerves in association to the transverse process varies anatomically, depending on the segmental level. The C8 medial branch nerves cross in a manner similar to the upper thoracic medial branch nerves at the superolateral aspect of the transverse process (personal communication, Frank Willard, PhD, anatomist). T1-T3 and T9-T10 medial branches cross at the superolateral aspect of the transverse process, T4-T8 medial branches cross above the transverse process, and T11-T12 medial branches cross at the junction of the superior articular process and transverse process similar to the lumbar levels. The variability of the medial branch nerve locations is demonstrated by black lines. The C8 medial branch location variability is unknown, so we are not demonstrating variability lines. The medial branch location variability is greatest in the midthoracic spine region (i.e., T4-T8). Therefore, phenol chemodenervation should be considered when denervating these nerves. (Modified with permission from Chua WH, Bogduk N: The surgical anatomy of the thoracic facet denervation. *Acta Neurochir [Wien].* 1195;136[3-4]:140-144.) (For a high-resolution version of this image, go to www.expertconsult.com.)

CHAPTER 23

Intercostal Nerve Injections

An intercostal nerve injection can be helpful for the treatment of painful intercostal neuropathy, herpes zoster, and rib fractures. It may also be useful for the diagnosis and treatment of uncommon abdominal or chest wall pain.

The absorption rate of local anesthetics is greater in the intercostal area because of the close proximity to vascular structures. Given this, one should be mindful of the concentration and volume of local anesthetic used for this procedure.

As with any procedure, careful patient selection is important. Patients with compromised pulmonary function (e.g., those with severe chronic obstructive pulmonary disease) may be poor candidates for this procedure because of the associated risk for pneumothorax and its resultant further respiratory compromise. Bilateral intercostal nerve blocks would not be recommended on the same day because of the attendant risk for pneumothorax and its potential complications.

Anatomy-guided "blind" injections can be performed with palpation of bone and soft tissue landmarks, but these techniques carry the risk for pneumothorax, particularly in the setting of chronic lung disease.

A bent needle tip (see Chapter 2) aimed dorsally toward the final target will help keep the tip in a safe location for both the fluoroscopic and ultrasound-guided techniques.

References

1. Shin DY, Lennard TA. Proximal upper extremity, trunk, and head blocks. In: Lennard TA, ed. *Physiatric Procedures in Clinical Practice*. Philadelphia: Hanley and Belfus; 1995:133.
2. Tucker G, Mather L. Absorption and disposition of local anesthetics: pharmacokinetics. In: Cousins M, Bridenbaugh P, eds. *Neural Blockade In Clinical Anesthesia and Management of Pain*. Philadelphia: Lippincott Williams & Wilkins; 1980:59.
3. Shanti CM, Carlin AM, Tyburski JG. Incidence of pneumothorax from intercostal nerve block for analgesia in rib fractures. *J Trauma*. 2001;51(3):536–539.
4. Holzer A, Kapral S, Hellwagner K, Eisenmenger-Pelucha A, Preis C. Severe pneumothorax after intercostal nerve blockade. A case report. *Acta Anaesthesiol Scand*. 1998;42:1124–1126.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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CHAPTER 23A

Intercostal Blockade: Fluoroscopic Guidance

Jonathan B. Stone, Michael A. Klein, and Michael B. Furman

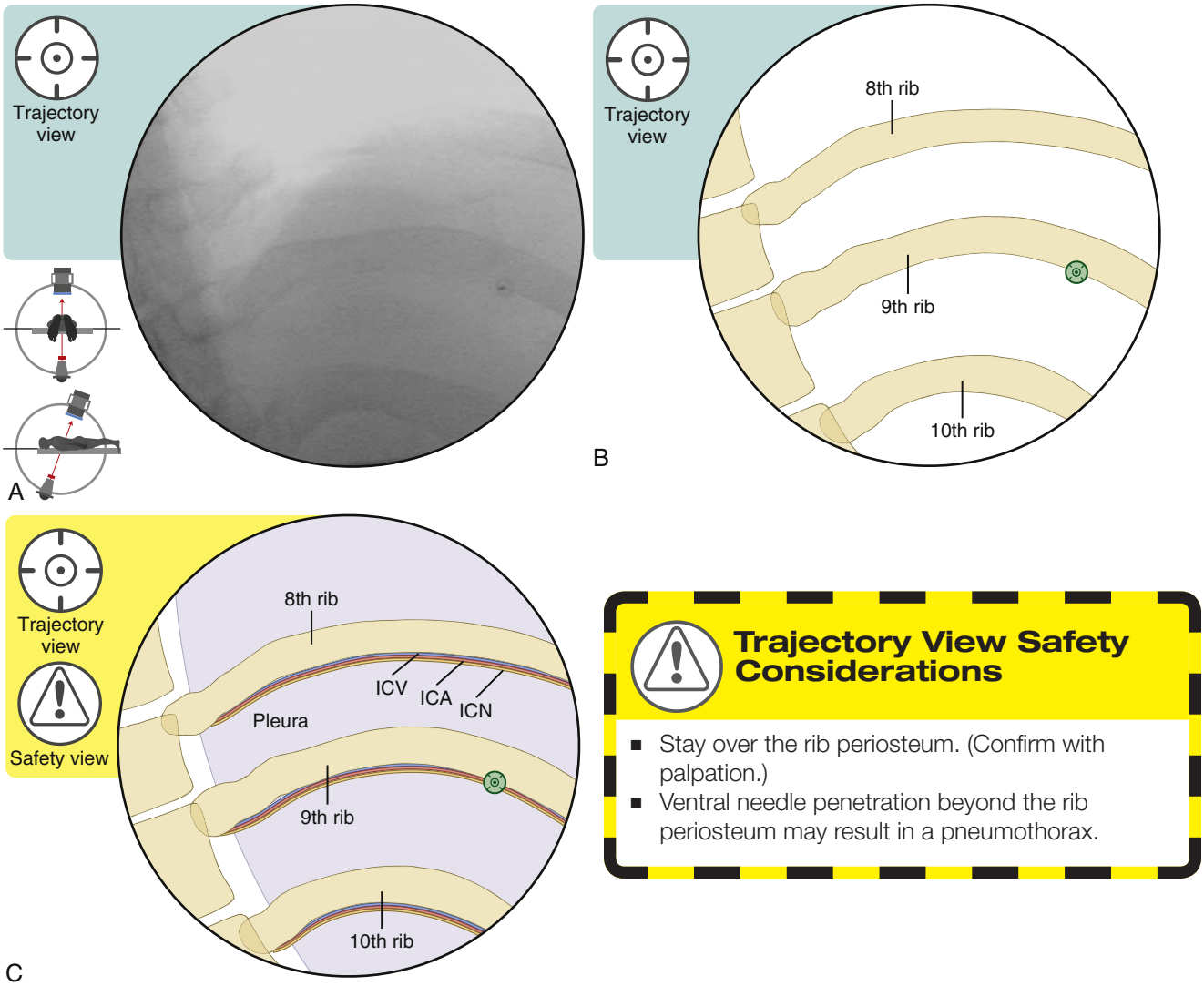
Typically, intercostal blockade may be performed with a trajectory view angled superiorly toward the inferior aspect of the intended costal margin, followed by the anteroposterior (AP) and lateral fluoroscopic views. The location is usually between 3 inches lateral to the spine and the posterior axillary line, but the injection may be performed at any area proximal to the site of pain. At the insertion point, the needle is "walked off" of the inferior border of the rib with an effort to maintain an inferior-to-superior needle trajectory until the needle "steps off" of the rib margin. The depth should be no more than 2 to 3 mm past the rib margin to avoid a potential pneumothorax. The pleura lie in close proximity to the ribs, and the risk for pneumothorax is significant if the needle is advanced too far ventrally.

Considering the layout of this book, images of the trajectory, AP, and lateral views are provided. Although these views may not be all necessary to obtain a successful intercostal nerve block, they may yield an additional margin of safety. Consider a hybrid US procedure (Chapter 23B) to visualize the pleura for additional safety.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 23A.1)

- **Confirm the level** (with the AP view).
- **Tilt the fluoroscope's image intensifier caudad** 15 to 20 degrees from the *true AP.*
- Lining up the corresponding ribs with a caudad tilt allows for the easier ability to "walk off" of the periosteum with an inferior-to-superior approach.
- No fluoroscope oblique is necessary.
- The target needle destination is at the inferior border of the corresponding rib. (Confirm with palpation.)
- **Place the needle parallel to the fluoroscopic beam.**



Trajectory View Safety Considerations

- Stay over the rib periosteum. (Confirm with palpation.)
- Ventral needle penetration beyond the rib periosteum may result in a pneumothorax.

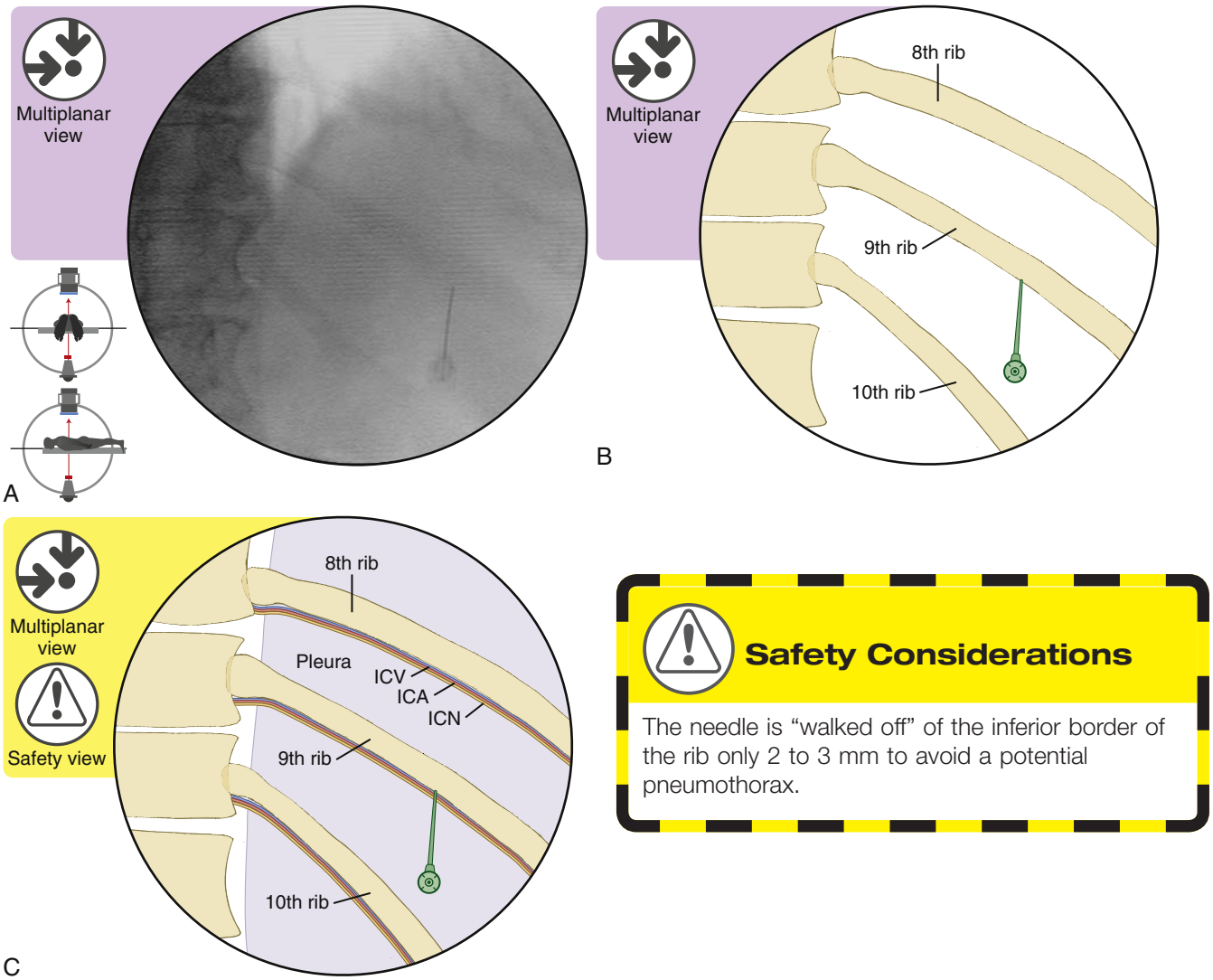
Fig. 23A.1. A, Fluoroscopic image of a trajectory view of a T9 intercostal nerve block with the needle in position at the inferior border of the ninth rib. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view (ICV, intercostal vein; ICA, intercostal artery; ICN, intercostal nerve).

Optimal Needle Position in Multiplanar Imaging

- After the needle touches the periosteum of the inferior costal margin, the fluoroscope is tilted to the AP position.
- With the use of a cephalad needle trajectory, the needle is slowly "walked off" of the inferior margin of the rib until the needle "steps off" of the rib margin.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 23A.2)

When needle position is optimal in the AP view, one may obtain a lateral image to document the final needle depth.



Safety Considerations

The needle is "walked off" of the inferior border of the rib only 2 to 3 mm to avoid a potential pneumothorax.

Fig. 23A.2. A, Fluoroscopic anteroposterior view with the ideal needle position for an intercostal nerve block at the ninth rib. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view (ICV, intercostal vein; ICA, intercostal artery; ICN, intercostal nerve).

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 23A.3)

Notes on Optimal Needle Positioning

The needle is advanced off of the inferior rib margin only 2 to 3 mm to avoid the potential for a pneumothorax. Consider a hybrid US procedure to visualize the pleura.

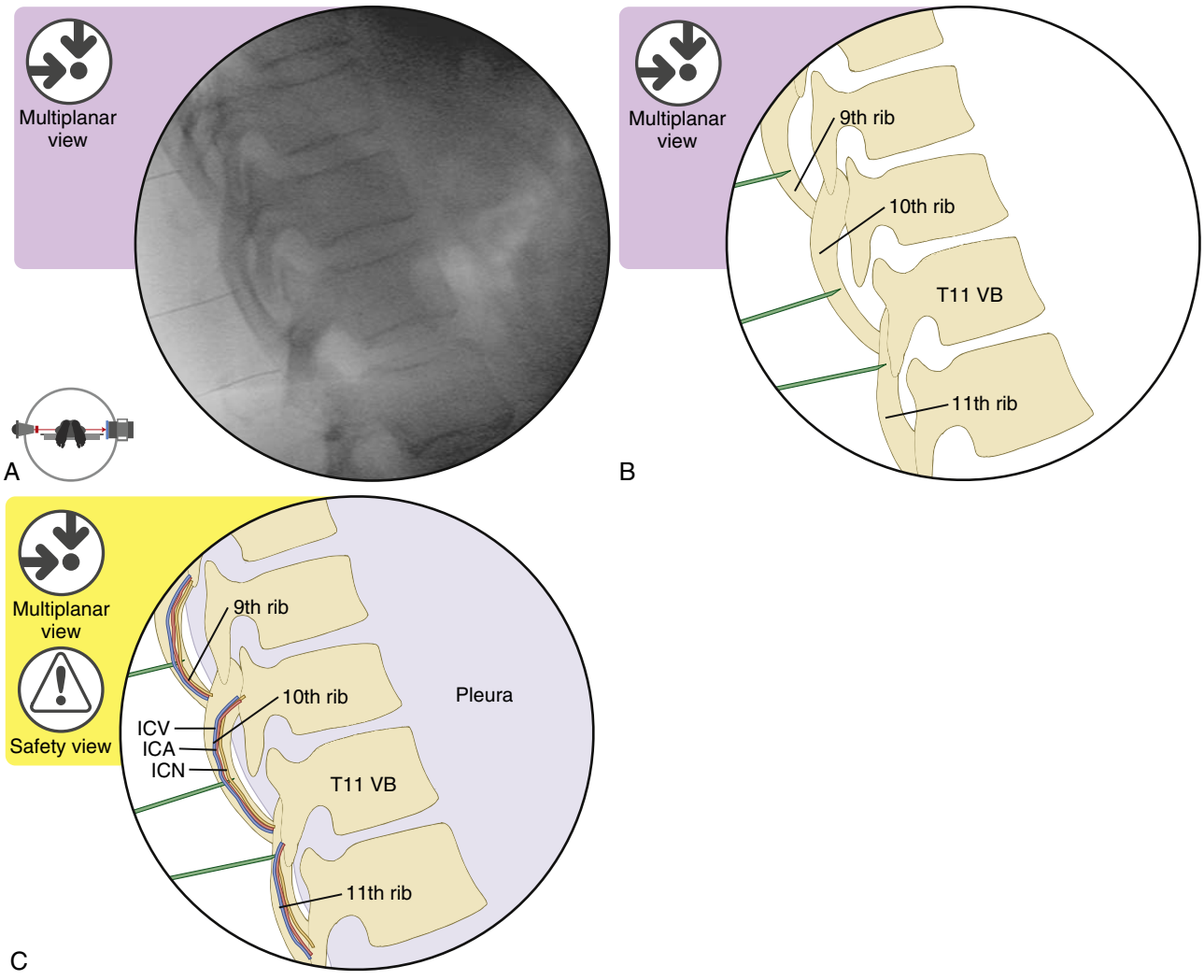


Fig. 23A.3. A, Fluoroscopic lateral view with the ideal needle position for intercostal nerve blocks at the ninth, tenth, and eleventh ribs. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal and Suboptimal Images (Fig. 23A.4)

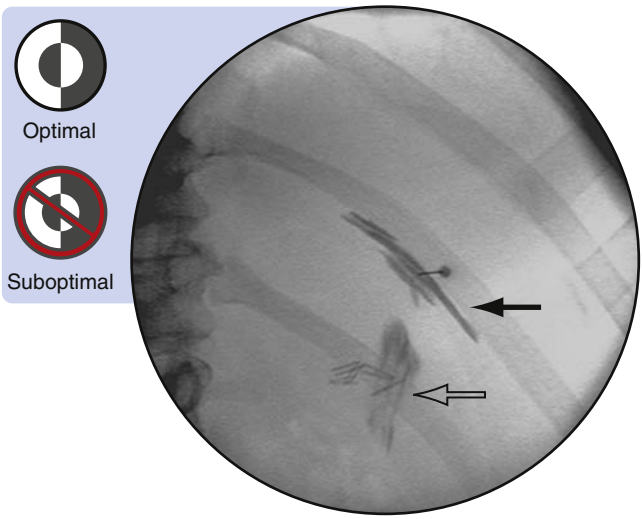


Fig. 23A.4. Anteroposterior fluoroscopic image of an intercostal nerve block at the inferior costal margin of the ninth rib with 0.5 cc of contrast (closed arrow). Also note the suboptimal flow pattern shown at the tenth rib (open arrow).

Optimal Image

Ideal contrast flow should follow along the inferior rib margin via the course of the intercostal nerve.

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CHAPTER 23B

Intercostal Nerve Injection, In-Plane Approach, Ultrasound Guidance

Shounuck I. Patel, Paul S. Lin, and Michael B. Furman

Unlike fluoroscopy, ultrasound guidance has a true "safety view" because ultrasound can be used to image the intercostal space in real time, while avoiding the underlying pleura. In addition, unlike fluoroscopy, ultrasound can be utilized to evaluate potential pneumothorax. Ultrasound-guided and fluoroscopy-guided intercostal nerve blocks have similar efficacy in pain relief. An additional technique (which will not be further described in this book) combines ultrasound guidance with neurostimulation to ensure proximity to the intercostal nerve for diagnostic accuracy.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 23B.1)

- Patient prone (prone, side-lying, or supine position to be adjusted depending on the region of pain).
- Interventionalist on the ipsilateral side that is to be injected.
- Ultrasound image cephalad and in line with the transducer (see Fig. 23B.1D, see Chapter 4).
- Linear ultrasound transducer positioned so the palpated target rib is in short axis.
- Injection target should be proximal to the region of pain along the rib.
- Insert the needle and advance in-plane to the transducer from caudad to cephalad to the inferior deep aspect of the target rib.

Fig. 23A.1. A, Typical setup with ultrasound in relation to patient.

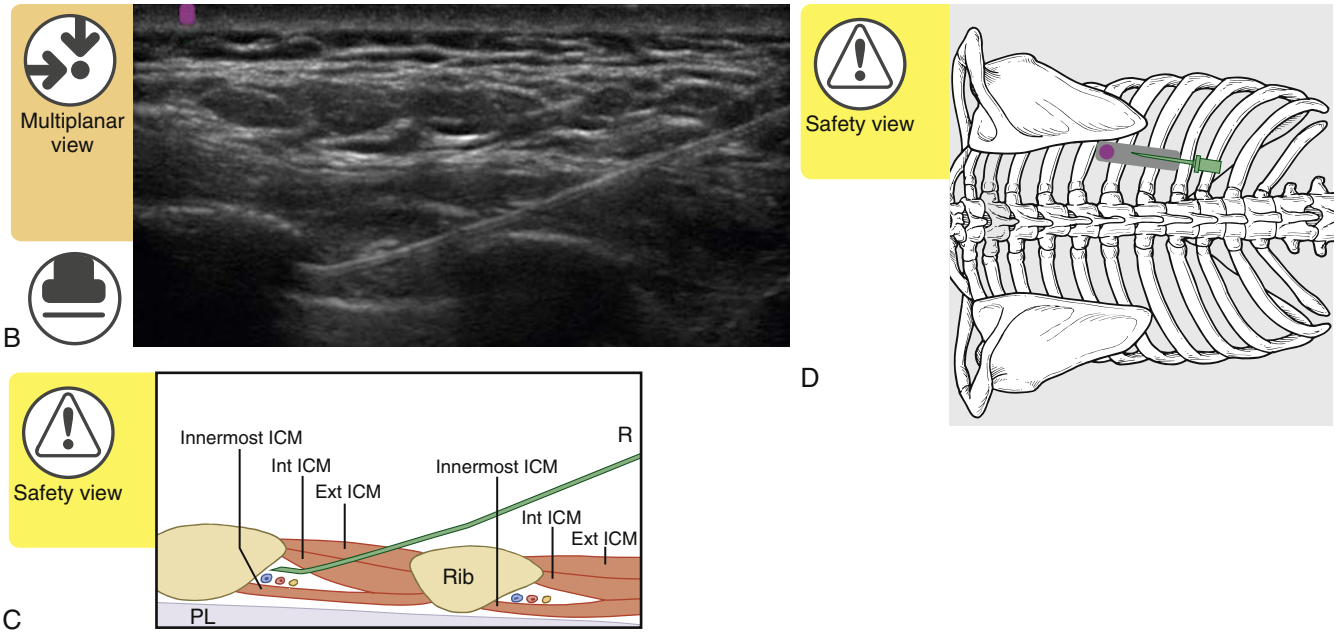


Fig. 23B.1. B, Ultrasound image of needle placement caudal to the target rib in short axis. **C**, Drawing of relevant radiolucent structures. The three intercostal muscle layers from superficial to deep are the external, internal, and innermost. The neurovascular bundle resides between the internal and innermost intercostal muscle layers at the undersurface of the inferior rib called the costal groove. The pleura are just deep to the innermost intercostal muscle layer. **D,** Skeleton with transducer placement.

In-Plane Technique Safety Considerations

- The pleurae are the shimmery layers in between the ribs just deep to the innermost intercostal muscles. Avoid needle placement into the pleurae.
- Take care not to lose visualization of the needle tip. If visualization is difficult because of habitus and/or angle of needle trajectory, switch to a low-frequency curvilinear transducer.
- A “walk-off” technique can be used in which the needle is directed to touch the inferior aspect of the rib and then redirected inferiorly, just deep to the costal groove.
- Once the needle is advanced under the rib costal groove, it cannot be visualized with ultrasound because of the acoustic shadow from the overlying rib. Do not advance deeper at this point due to risk for puncturing the pleurae.

Multiplanar View

We typically do not obtain an out-of-plane multiplanar confirmation for this technique.

Optimal Image

For optimal and suboptimal fluoroscopically guided images, please see Chapter 23A, Intercostal Nerve Injections, Fluoroscopic Guidance.

Suboptimal Needle Placement and Images (Fig. 23B.2)

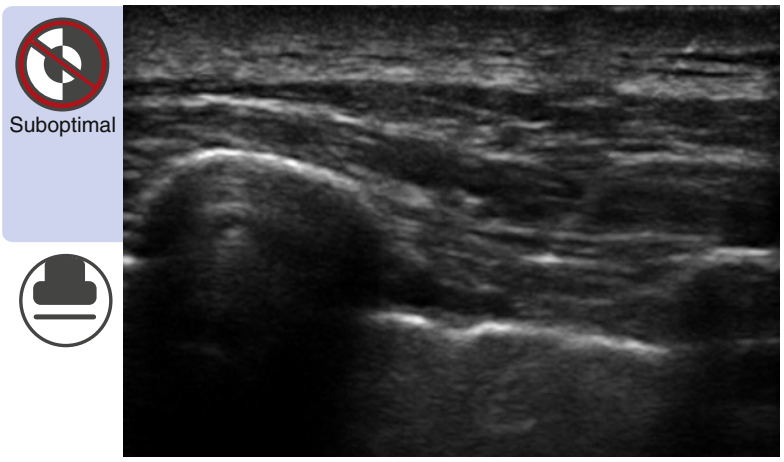


Fig. 23B.2. Poor needle tip visualization and needle trajectory that is too deep, far from the costal groove with potential pulmonary compromise.

References

1. Husain LF, Hagopian L, Wayman D, Baker WE, Carmody KA. Sonographic diagnosis of pneumothorax. *J Emerg Trauma Shock*. 2012;5(1):76–81.
2. Shankar H, Eastwood D. Retrospective comparison of ultrasound and fluoroscopic image guidance for intercostal steroid injections. *Pain Pract*. 2010;10(4):312–317.
3. Patel SI, Joshi MY. Neurostimulation with ultrasound guidance for intercostal nerve block. *PMR*. 2013;5(10):903–905.

Thoracic Disc Access

CHAPTER 24

Justin J. Petrolla and Michael B. Furman

This chapter describes an extradural oblique technique for efficiently and safely accessing the thoracic disc. As with lumbar discography, the final needle tip target is the geometric center of the disc's nucleus pulposus.

A single-needle technique is preferred for thoracic disc access. However, a double-needle technique can be used with either a combination of 18 G introducer and 22 G intradiscal needles or 20 G introducer and 25 G intradiscal needles. The thoracic discs are generally narrower than the lumbar discs, so a thinner diameter needle may enable easier access. The needle tip can be slightly bent as described in Chapter 2 to optimize needle navigation. However, we do not suggest using a bent needle when navigating into narrow disc spaces.

The trajectory view used for this technique is similar to that used for the lumbar technique (Chapter 17) (i.e., inserting from lateral to superior articular process (SAP) between the vertebral end plates); however, the thoracic spine has an additional limitation that the needle must enter medial to the rib margins. The trajectory view used for thoracic discography is similar to that used for thoracic infraneural transforaminal injections (Chapter 21). There is a difference in the anatomy between lower, middle, and upper thoracic levels. The more cephalic lamina is wider, making it more challenging to access the disc's geometric center above T5-T6. We recommend a needle entry contralateral to the more painful side unless there are prohibiting issues. Multiplanar imaging should be used to advance the needle into its final position.

Thoracic provocation discography is a developing procedure with many similarities to lumbar provocation discography. As with the lumbar spine, imaging techniques alone cannot sufficiently identify the thoracic disc that causes pain in a patient. Data collection includes pain provocation (i.e., none, discordant, or concordant) correlated with the patient's clinical scenario. It also includes contrast volumes and disc architecture (nucleogram and postdiscography computed tomography [CT]).

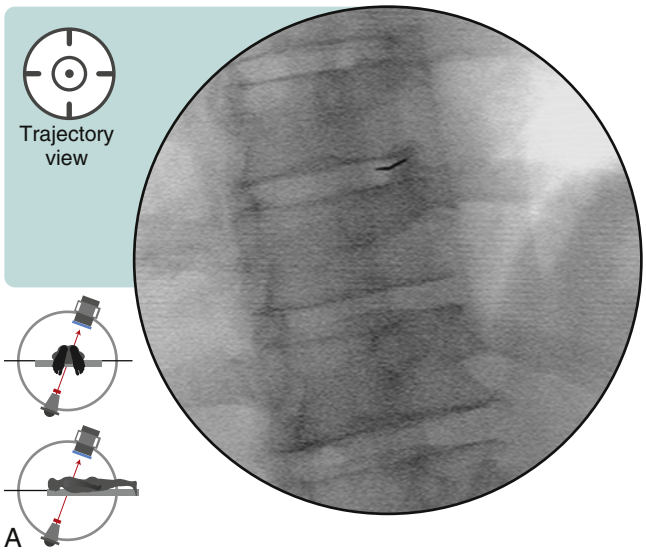
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 24.1)

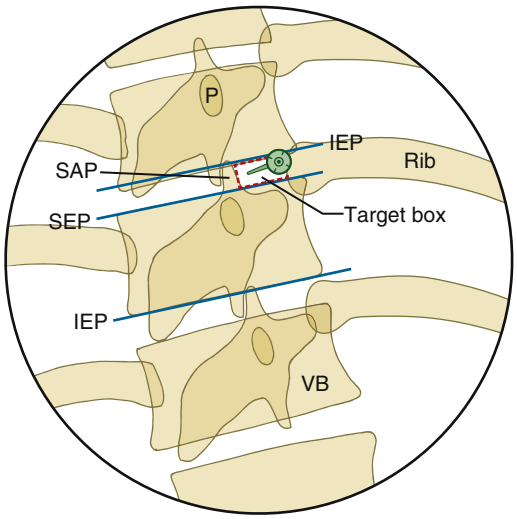
- **Confirm the level** (with the anteroposterior view).
- **Tilt the fluoroscope's image intensifier** cephalad or caudad.
- Line up the vertebral superior and inferior end plates with an appropriate orientation for each individual level.
- **Oblique the fluoroscope's image intensifier** ipsilateral to needle entry.
- Optional: Place a pillow lateralized ipsilateral to the needle entry side to obtain 5 to 10 degrees of additional obliquity.
- Position the fluoroscope such that the SAP is bisecting or nearly bisecting the diameter of the superior end plate.
- The target needle destination is the disc space immediately lateral to the junction of the inferior SAP and superior end plate and medial to the rib margins. **There is a target "box" formed by the superior end plate (SEP) inferiorly, the inferior end plate (IEP) superiorly, the SAP medially, and the rib laterally.**
- Adjust the degree of angulation for each individual intervertebral disc level.
- **Place the needle** parallel to the fluoroscopic beam.

Notes on Positioning in the Trajectory View

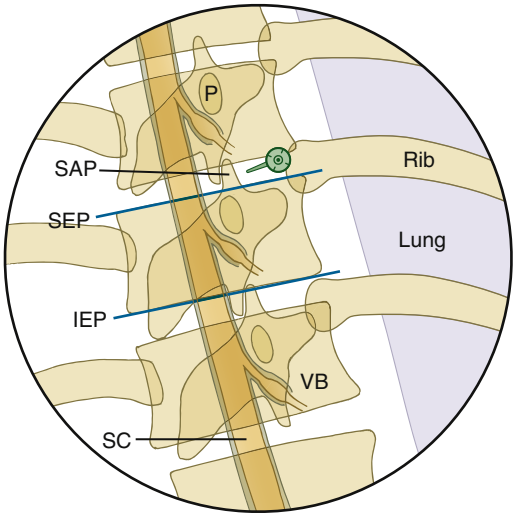
- For each level, the setup is individualized by changing the oblique angulation and tilting the image intensifier.
- For time efficiency and to minimize radiation, place needles for all intended levels sequentially in the trajectory view. Then, rotate to the anteroposterior and lateral views to adjust all needle tip positions. If needed, perform minor adjustments. This will minimize both C-arm and patient movement as well as radiation.



A



B



C

Trajectory View Safety Considerations

- Avoid the spinal nerve.
  - Remain toward the base of SAP (i.e., "low in the hole").
- Avoid the dura.
  - While advancing the needle toward the disc, do not go too far medial or lateral. Remain immediately lateral to the junction of the superior end plate and SAP. Attempt to enter the disc "low in the hole" to avoid the exiting spinal nerve.
  - Do not drive too far medial until entering the disc. A medial-straying needle can enter the dura.
- Avoid puncturing the lungs by staying on the trajectory path and not straying ventrally or laterally.

Fig. 24.1. A, Fluoroscopic image of a trajectory view with the needle in position. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

See Table 17A.1, Using AP and Lateral Views to Interpret Needle Tip Position.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 24.2)

The "true" anteroposterior visualization of each individual intervertebral disc is imperative.

The disc's geometric center typically coincides with the position of the spinous process from the superior vertebral body.

- Avoid advancement beyond the geometric center of the intervertebral disc (i.e., the nucleus pulposus).
- After obtaining intradiscal access, make only minor adjustments to ensure that the needle tip is medially oriented. However, the main advancement should be done in the lateral safety view.

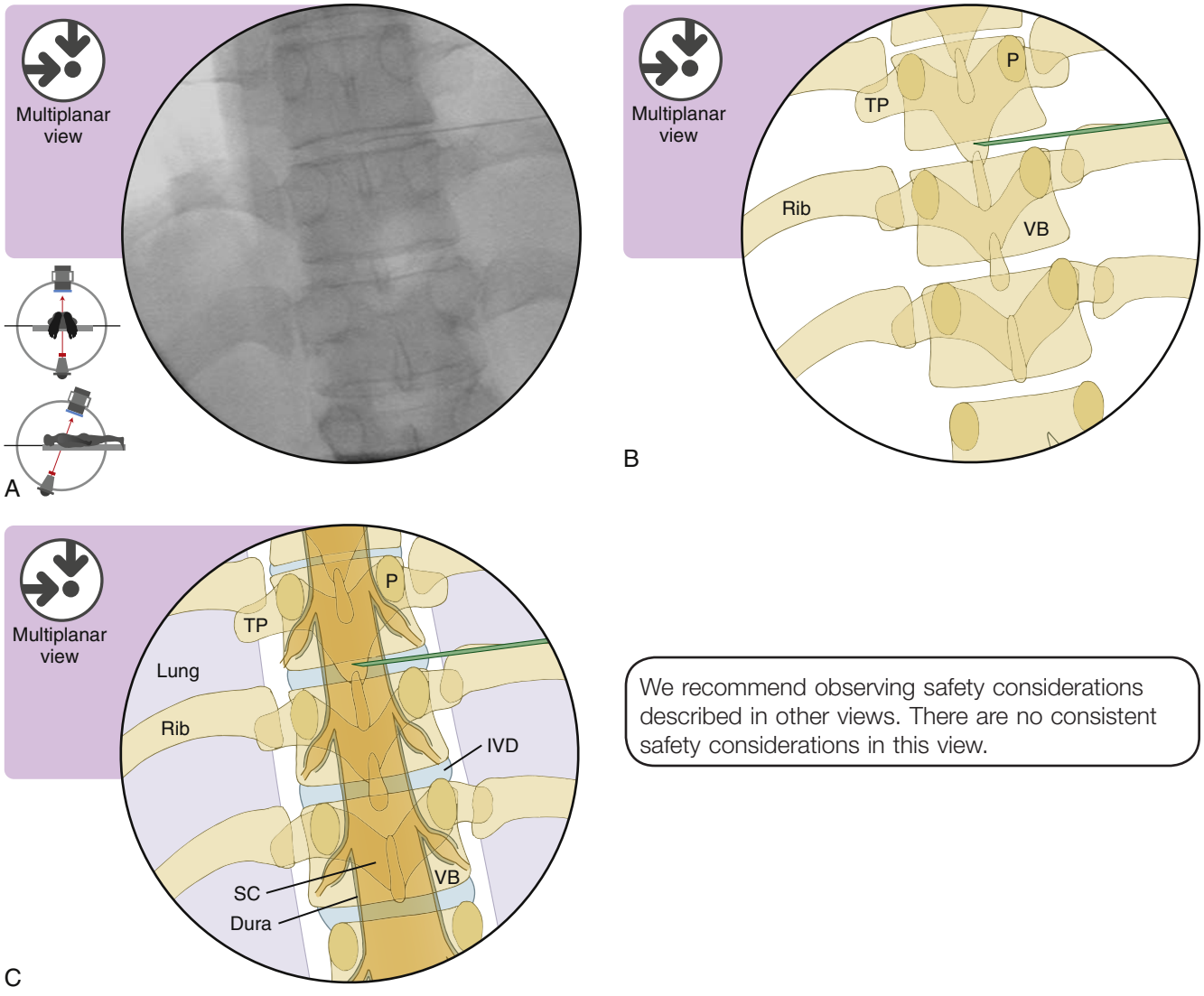


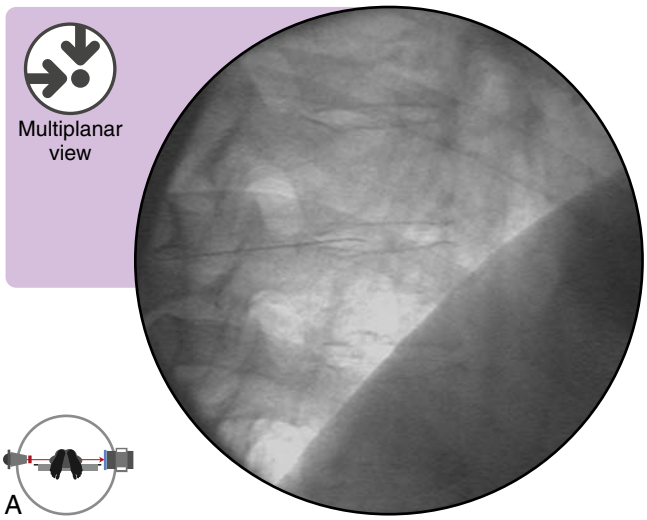
Fig. 24.2. A, Fluoroscopic anteroposterior view with the ideal needle position. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

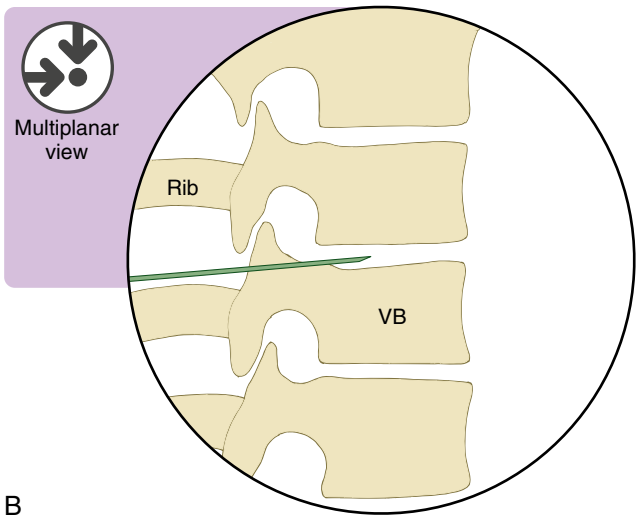
OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 24.3)

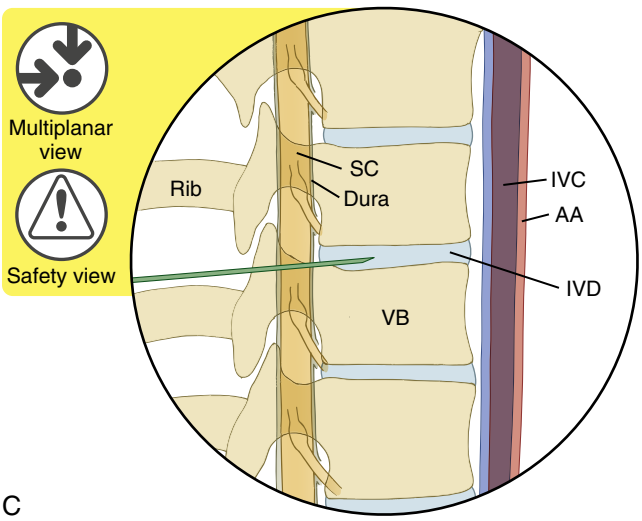
Position the C-arm to obtain a "true" lateral view of each intervertebral disc for the advancement of the needle. This view is the safety view.

Notes on Optimal Needle Positioning

- The target needle position is the geometric center of the intervertebral disc (i.e., the nucleus pulposus).
- The C-arm may need to be transitioned multiple times from the lateral and anteroposterior views to safely and successfully navigate the needle.







Safety Considerations

- Avoid the ventrally located aorta and vena cava.
  - Do not advance too ventrally.
- Avoid the spinal canal.
- Confirm that the needle is intradiscal before advancing the needle tip medially to avoid dural puncture dorsal to the disc.

Fig. 24.3. A, Fluoroscopic lateral view with the ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images (Fig. 24.4)

- Ideal flow should begin and remain within the nucleus pulposus.
- For normal and non-degenerated discs, the flow pattern should have a "cotton ball" or "lobular" appearance on the nucleogram.
- For degenerated discs, the flow pattern should appear "irregular," "fissured," or "ruptured" on the nucleogram.

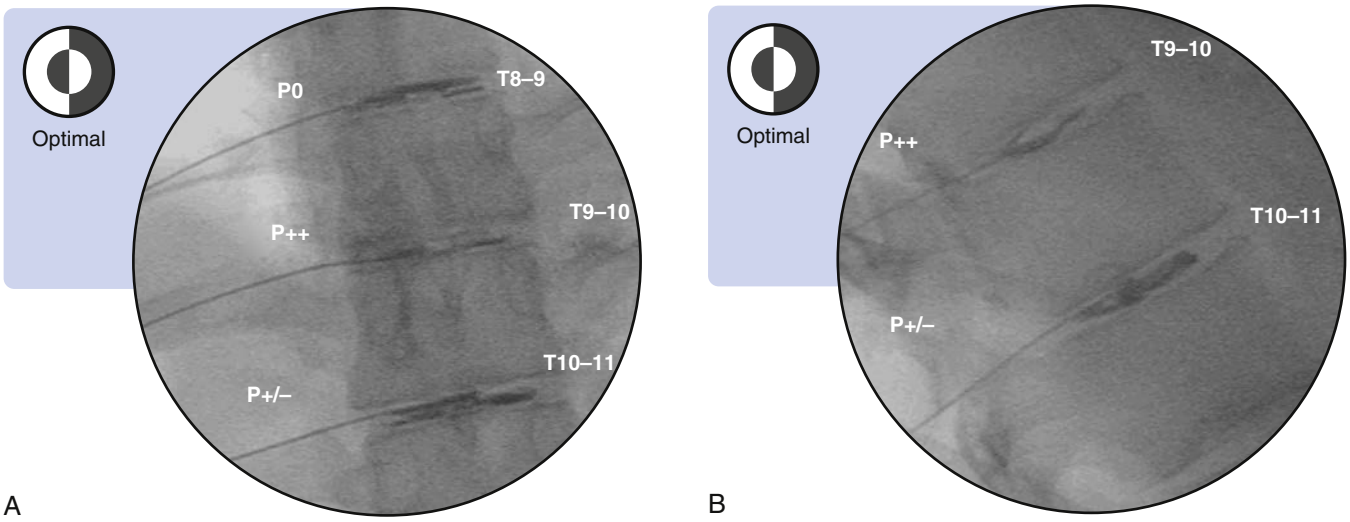


Fig. 24.4. A, Anteroposterior fluoroscopic image of thoracic discography at T8-T9, T9-T10, and T10-T11 with 1 cc of contrast within each disc. **B,** Lateral fluoroscopic image of thoracic discography at T9-T10 and T10-T11 with 1 cc of contrast.

Please see Chapter 17A, Lumbar Provocation Discography/Disc Access, for information about the following:

- Pain response interpretation
- Nucleograms
- Antibiotics
- Postdiscography computed tomography scanning and its usefulness and interpretation

Suggested Readings

Bogduk N, ed. *Practice Guidelines for Spinal Diagnostic and Treatment Procedures*. 2nd ed. San Francisco: International Spine Intervention Society; 2013:315–323.

Schellhas KP, Pollei SR, Dorwart RH. Thoracic discography. A safe and reliable technique. *Spine (Phila Pa 1976)*. 1994;19(18):2103–2109.

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CHAPTER 25

Cervical Interlaminar Epidural Steroid Injection—Paramedian Approach

Justin J. Petrolla, Amir S. Tahaei, Kirk M. Puttlitz, Michael A. Klein, and Michael B. Furman

Cervical interlaminar epidural steroid injections are indicated for radicular pain with or without axial neck pain. The interlaminar approach is well suited for delivering medication to bilateral and/or multilevel cervical sites. C7-T1 level is typically targeted since it has the largest posterior to anterior distance between the ligmantum flavum and dura/spinal cord (SC). Also, the lower cervical levels are more likely to have an intact and fused midline ligamentum flavum. Preprocedure MRI review is helpful to examine the posterior epidural space dimensions. If the posterior epidural space is minimal to nonexistent at C7-T1, choose the T1-T2 segment.

After placing the needle using a trajectory view, it is advanced using multiplanar imaging, emphasizing on safety while visualizing the needle tip depth as it approaches the ventral interlaminar line (VILL) in the contralateral oblique (CLO) view and/or the spinolaminar line in the lateral view. We recommend visualizing the tip depth using CLO and/or lateral views rather than depending solely on the needle tip (stepping off the lamina). Typically, CLO view has better visualization than the lateral view since the shoulders frequently obstruct clear cervicothoracic region visualization in the lateral view. See Chapter 3 for more detailed CLO visualization explanation.

The epidural space is accessed by advancing the needle through the ligamentum flavum using the classic loss of resistance (LOR) technique coupled with multiplanar fluoroscopic imaging and real-time contrast visualization. The final location of the needle tip should be at the midline or slightly off the midline for more unilateral or asymmetric symptoms.

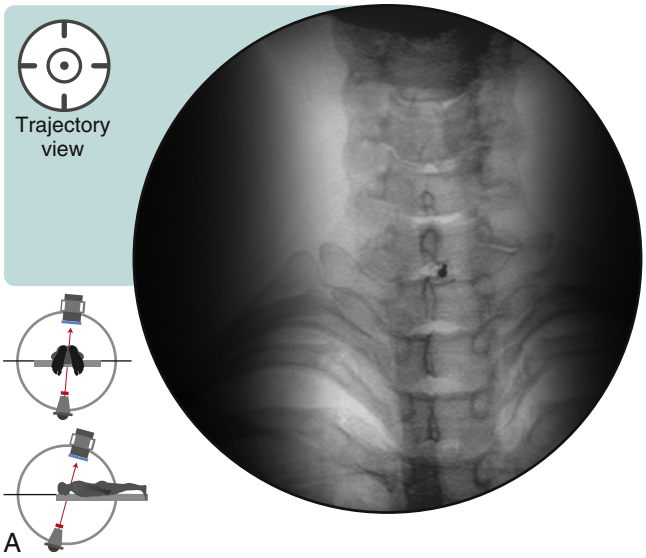
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

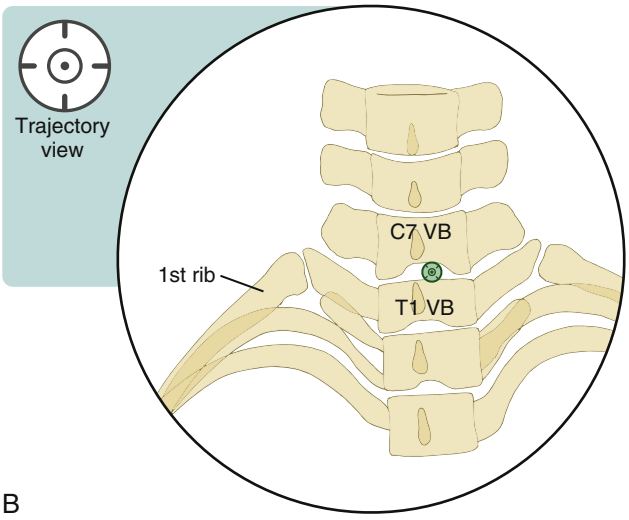
Trajectory View (Fig. 25.1)

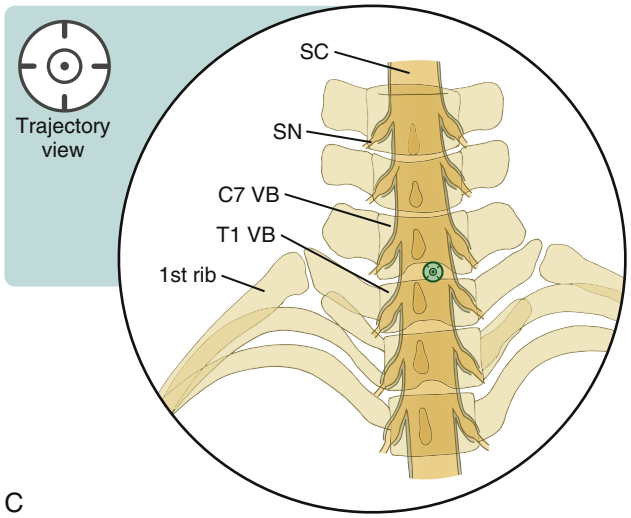
- **Confirm the level** with the anteroposterior (AP) view.
- **Tilt the fluoroscope caudad.**
- Maximize/optimize the targeted interlaminar space radiolucency with crisp laminar edges (usually C7-T1) using caudad or cephalad tilt.
- **Oblique** slightly (approximately 5–10 degrees) toward the symptomatic side (right side in this case).
- The needle is placed directly at the midline or just ipsilateral to the midline on the painful side in the target radiolucent interlaminar space.
- Because this is the trajectory view**, place the needle parallel to the fluoroscopic beam**.

Notes on Positioning in the Trajectory View

- Initial needle placement should be shallow in the soft tissues to avoid puncturing the dura and contacting SC.
- Interlaminar placement and further needle advancement can then be performed after rotating the C-arm into the lateral or CLO safety view. It is not necessary to "walk off" the lamina.
- There are no consistent radiolucent safety considerations in this trajectory view.







The needle should not be advanced too far ventrally in this view. We recommend observing the safety considerations demonstrated in other views (CLO and lateral) to visualize the corresponding landmarks.

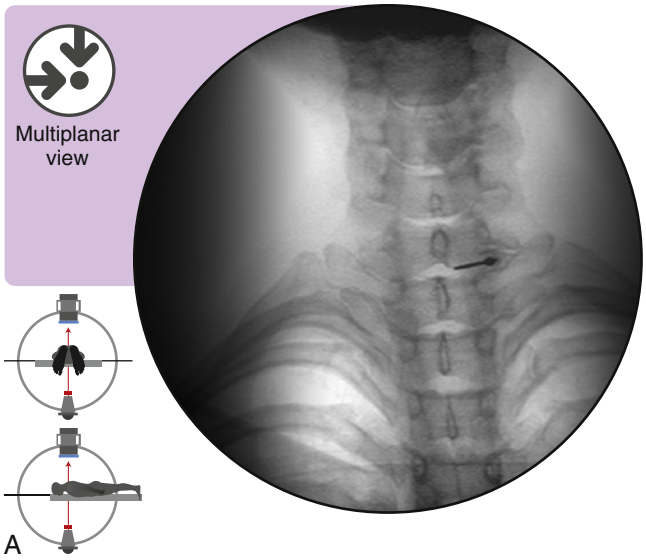
Fig. 25.1. A, Fluoroscopic image of a trajectory view with the needle in position at the C7-T1 interlaminar space with 5 to 10 degrees of ipsilateral oblique. The needle tip is slightly to the right of the midline. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view. Note that this is not the safety view for this procedure. This image is used to emphasize the location of the spinal cord (SC).

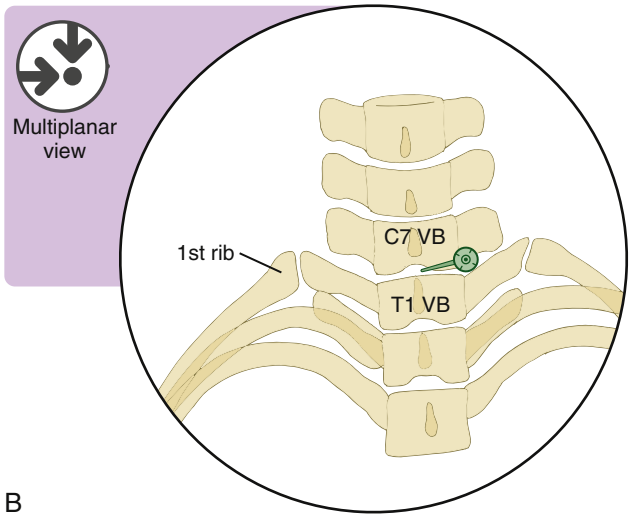
Optimal Needle Position in Multiplanar Imaging

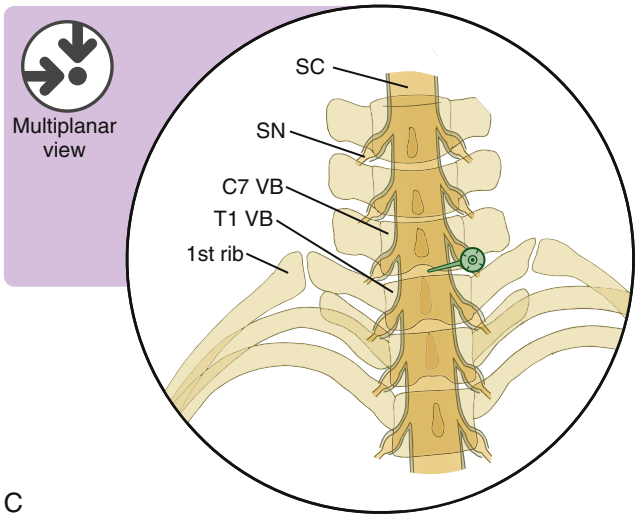
We recommend a minimum of two views, including the AP view (approaching midline) and the CLO view to confirm that the tip has not respectively crossed the VILL. Optionally, use the "true" lateral to confirm that the tip has not crossed the spinolaminar line. Advance the needle tip safely toward the target only with the use of the CLO and/or "true" lateral safety view. The AP view is used to confirm laterality or midline placement but is not a safety view.

OPTIMAL NEEDLE POSITIONING IN THE AP VIEW (FIG. 25.2)

The needle should ideally remain close to the midline. The needle tip may be targeted slightly off the midline for the treatment of more unilateral symptoms.







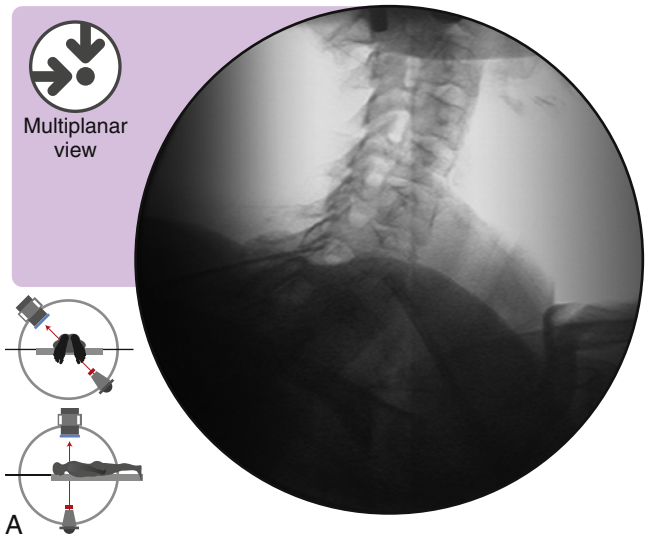
There are no consistent radiolucent safety considerations in this trajectory view. To avoid dural and SC contact, **the needle should not be advanced too far ventrally in this view.** We recommend observing the safety considerations demonstrated in other views (CLO and/or lateral) to visualize the corresponding landmarks.

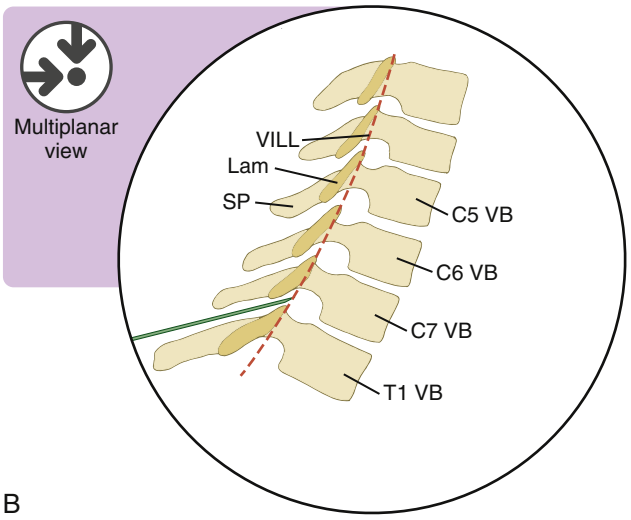
Fig. 25.2. A, Fluoroscopic "true" AP view with the pre-loss of resistance, precontrast needle position near midline. This is a paramedian approach toward the right with the needle tip near the midline. The needle should not be advanced any further since this is not a safety view. **B,** Radiopaque structures, AP view. **C,** Radiolucent structures, AP view.

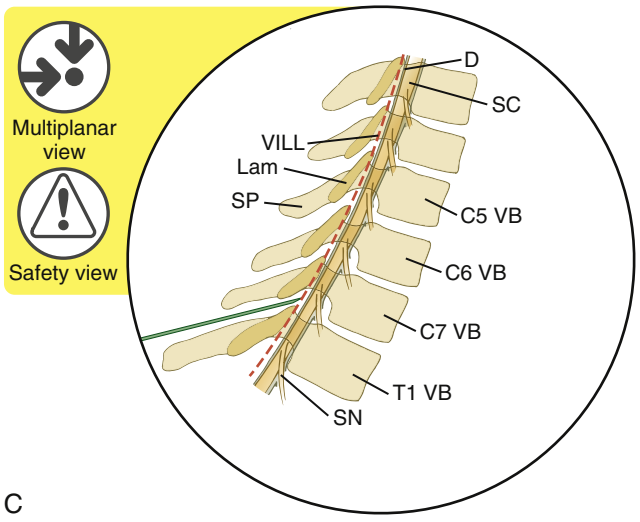
OPTIMAL NEEDLE POSITIONING IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 25.3)

After confirming the needle tip position in AP view, the C-arm should now be positioned in the CLO safety view. For more discussion regarding CLO, please see Chapter 3, Fig. 3.21.

- Optimal needle positioning: CLO (i.e., obliqued to the opposite side of the needle tip), with the needle confirmed as being at the midline or slightly closer to the more symptomatic side. An initial starting angle will be about 60 degrees CLO.
- Under the CLO view, advance the needle slowly, intermittently, or continuously checking for LOR. LOR should be encountered near the VILL. The VILL is the line that connects the posterior edge of the neuroforamen with the anterior margin of the football-shaped lamina. Note that the needle may appear to be more ventral if the tip crosses the midline to the side ipsilateral to the image intensifier.







Safety Considerations

Cautiously approach and traverse the VILL with a LOR technique. Avoid puncturing the dura (D) and contacting the spinal cord (SC).

Fig. 25.3. A, Fluoroscopic contralateral oblique view (i.e., safety view) with the pre-loss of resistance position at the ventral edge of the football-shaped lamina (Lam). The needle tip may be advanced with the loss of resistance expected at or slightly past the ventral interlaminar line (VILL). **B,** Radiopaque structures, contralateral oblique view. **C,** Radiolucent structures, contralateral oblique view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW

After confirming the needle tip position in AP and CLO views, the C-arm may now be positioned in the lateral safety view for further multiplanar confirmation.

PATIENT PRONE, "TRUE" LATERAL (I.E., 90 DEGREES OBLIQUE) (FIG. 25.4)

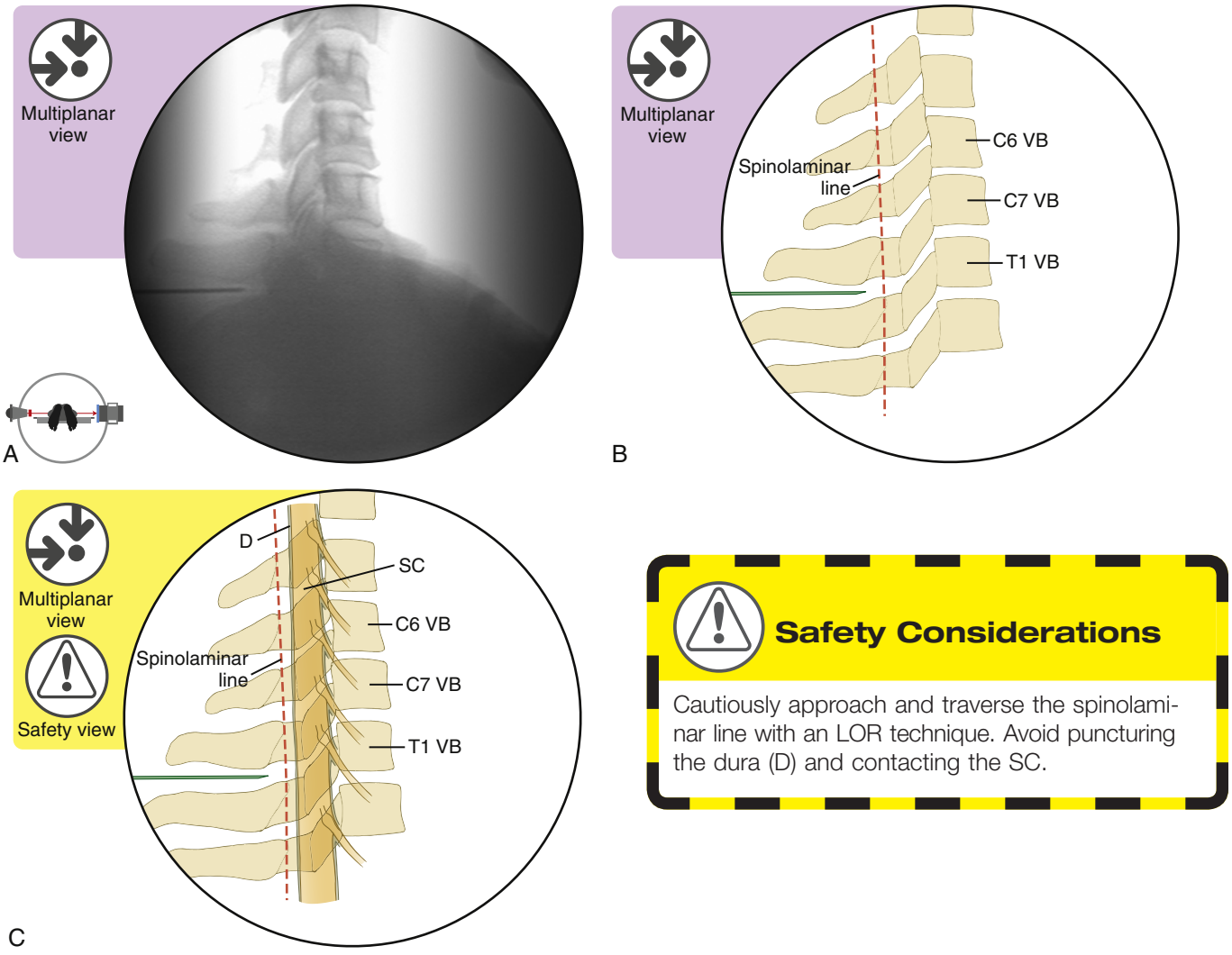


Fig. 25.4. A, Fluoroscopic "true" lateral view (i.e., safety view) with the needle tip approaching the spinolaminar line. The loss of resistance is expected at or near the spinolaminar line. **B,** Radiopaque structures, "true" lateral view. **C,** Radiolucent structures, "true" lateral view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL SAFETY VIEW

We recommend a minimum of two views, including the AP (approaching midline) and either or both of the CLO and "true" lateral views to confirm that the tip has not gone too ventral.

- If the needle is advanced ventral to VILL in CLO view (or spinolaminar line in the lateral views) and LOR has not yet been encountered, then do the following:
  - Check the AP view to make sure that the needle tip is on the desired side and/or has not strayed too far laterally.
  - Re-stylet the needle to make sure that a blood clot or some other tissue substance has not occluded the needle lumen, thereby confounding the perception of LOR.
  - Inject contrast to see if the needle tip is indeed already in the epidural space, despite a lack of perceived LOR.
- If there is a high resistance on injection or patient complaints of pain or paresthesias, it may suggest that the needle is contacting the SC or a nerve root.
  - Confirm position and withdraw as appropriate.
  - Do not inject contrast or injectate because this may precipitate clinically significant nerve or SC injury.
  - Do not oversedate the patient because this may hinder patient reporting of these helpful warning symptoms.
- While advancing the needle via the CLO or "true" lateral safety view, we recommend intermittently switching back to the AP view to confirm the needle tip position relative to the midline. The utility of the CLO or "true" lateral is predicated upon slight ipsilateral or near midline needle tip placement.
- **When LOR is achieved with either of the techniques, inject contrast to confirm epidural placement.**

Optimal Images (Fig. 25.5)

Optimal Image (Please see Table 12.1 to differentiate epidural from non-epidural flow)

Contralateral oblique view:

- When the needle tip is contralateral: Contrast flow should layer immediately ventral to the lamina along VILL (i.e., the line that connects the posterior edge of the neuroforamen with the anterior margin of the football-shaped lamina).

Lateral view:

- Contrast flow should layer immediately ventral to the bases of the spinous processes along the spinolaminar line (i.e., the line that connects the ventral edge of the spinous processes).

AP view:

- Contrast flow typically appears as an irregular, asymmetric cloud, possibly lateralizing to one side.
- Contrast dye may outline epidural fat "bubbles."
- Contrast dye may outline exiting spinal nerves.
- Contrast immediately contacts the medial pedicle.
- Contrast may spread rostral and caudad for many levels; however, central stenosis may limit such spread.

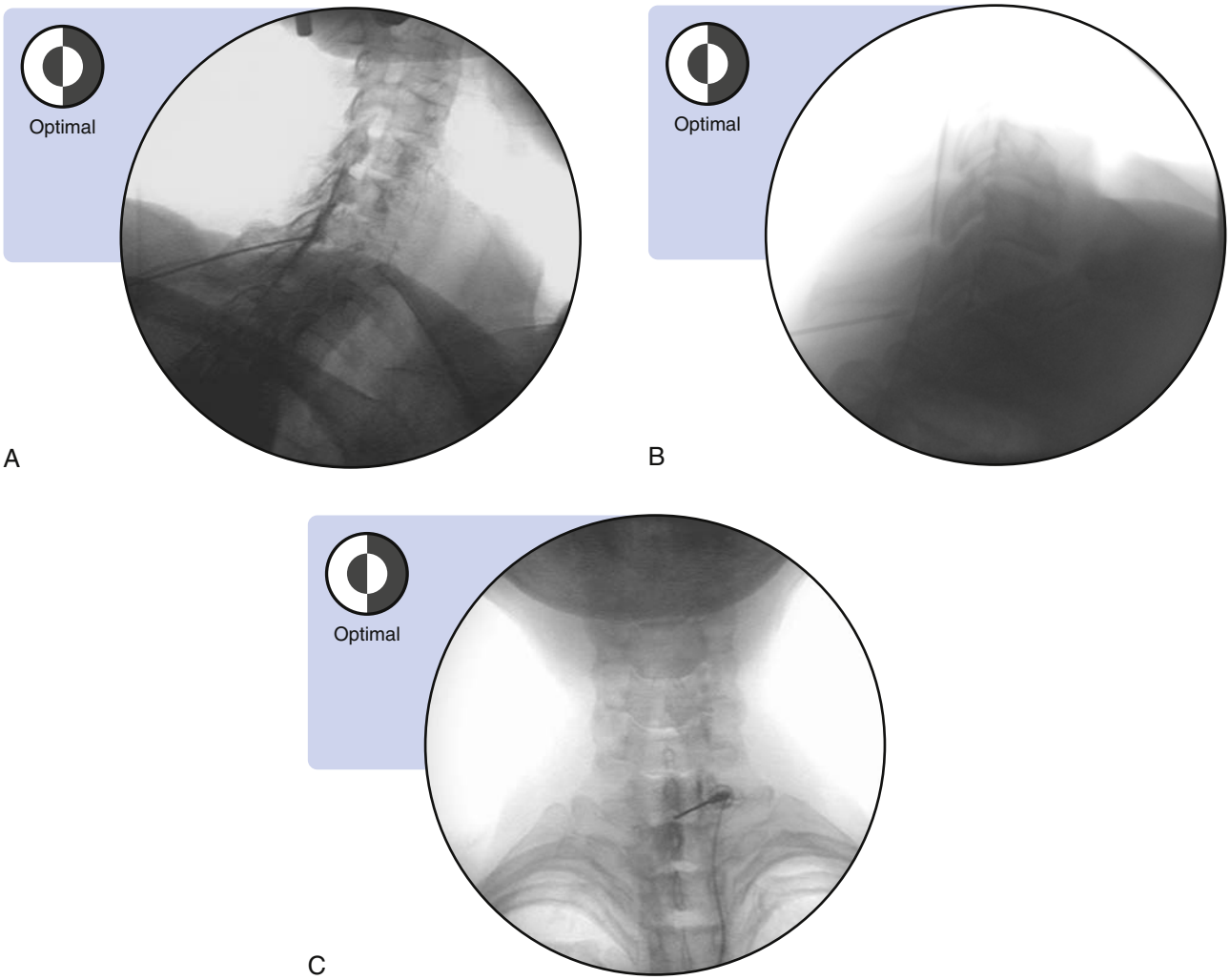


Fig. 25.5. A, Contralateral oblique (CLO) fluoroscopic image of a cervical interlaminar epidural steroid injection with 0.5 cc of contrast medium. **B,** "True" lateral fluoroscopic image of a cervical interlaminar epidural steroid injection with 0.5 cc of contrast medium. Note that the landmarks are not as well visualized as those in the CLO view. **C,** Anteroposterior fluoroscopic image of a cervical interlaminar epidural steroid injection with 0.5 cc of contrast medium.

Suboptimal Images (Figs. 25.6 to 25.8)

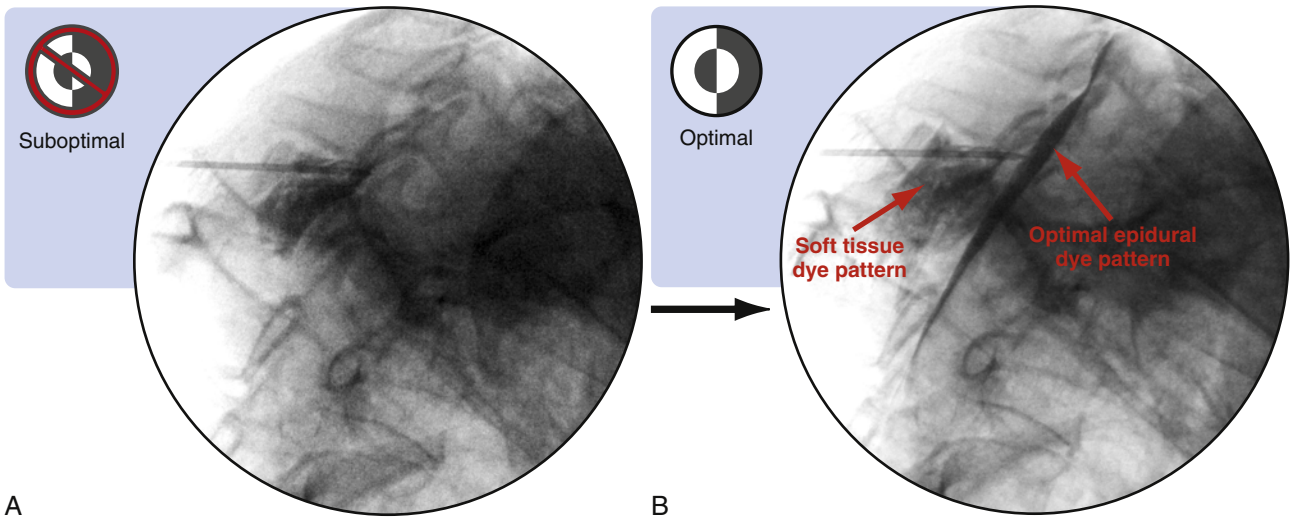


Fig. 25.6. A, Cervical interlaminar epidural steroid injection (ESI), contralateral oblique view. The needle is located dorsal to the ventral interlaminar line (VILL). Note the posterior contrast extravasation into the dorsal soft tissue, with a striated fascial pattern. This amorphous pattern typically occurs with a false loss of resistance (LOR). **B,** After the needle tip was advanced ventrally toward the epidural space, a true LOR was encountered. There is now an optimal contrast pattern in the dorsal epidural space.

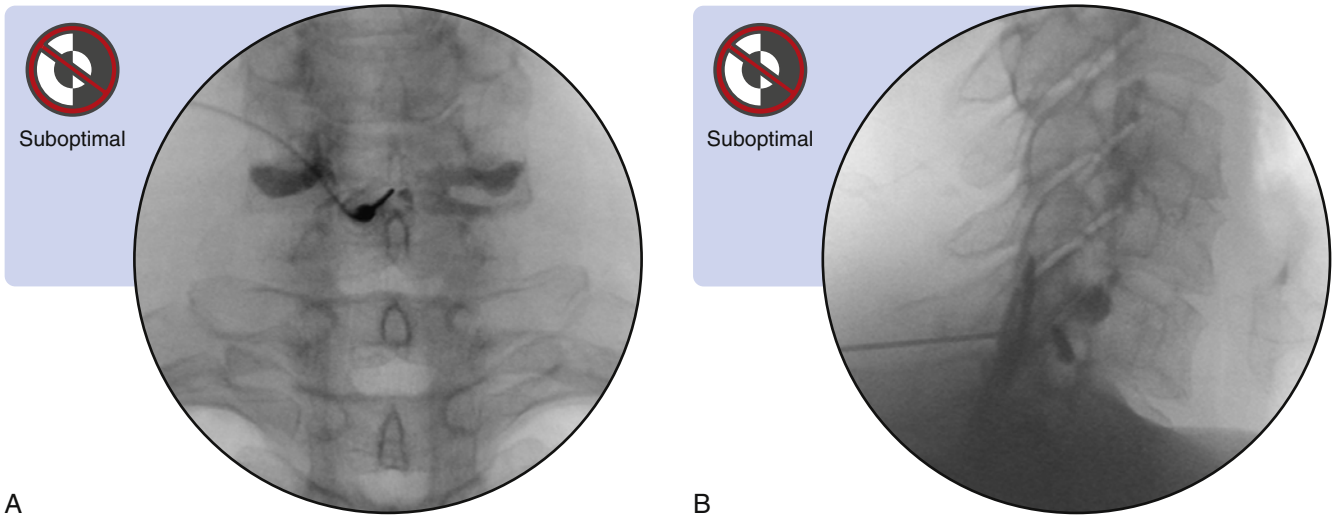


Fig. 25.7. A, Cervical C6-C7 interlaminar epidural steroid injection, anteroposterior view, demonstrating communication with the space of Okada and bilateral C6-C7 Z-joints. **B,** Cervical interlaminar epidural steroid injection, lateral view of the same patient, demonstrating contrast extravasation in the posteriorly located space of Okada and bilateral Z-joints. Although there is some optimal flow in the epidural space, this is still a suboptimal contrast pattern.

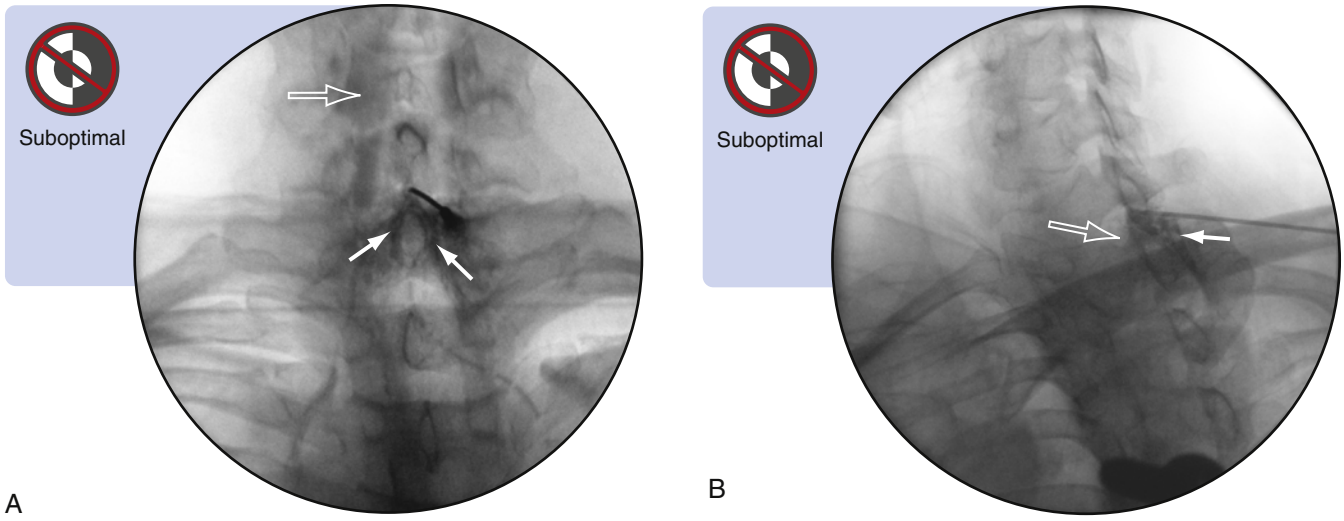


Fig. 25.8. A, Anteroposterior (AP) view demonstrating non-epidural contrast on either side of the spinous process (closed arrows). This is actually a "mixed" pattern with epidural flow as well (open arrow). **B,** Corresponding lateral view demonstrating that most of the contrast flow is dorsal to the desired epidural space and between the lamina (closed arrow), along with epidural flow (open arrow).

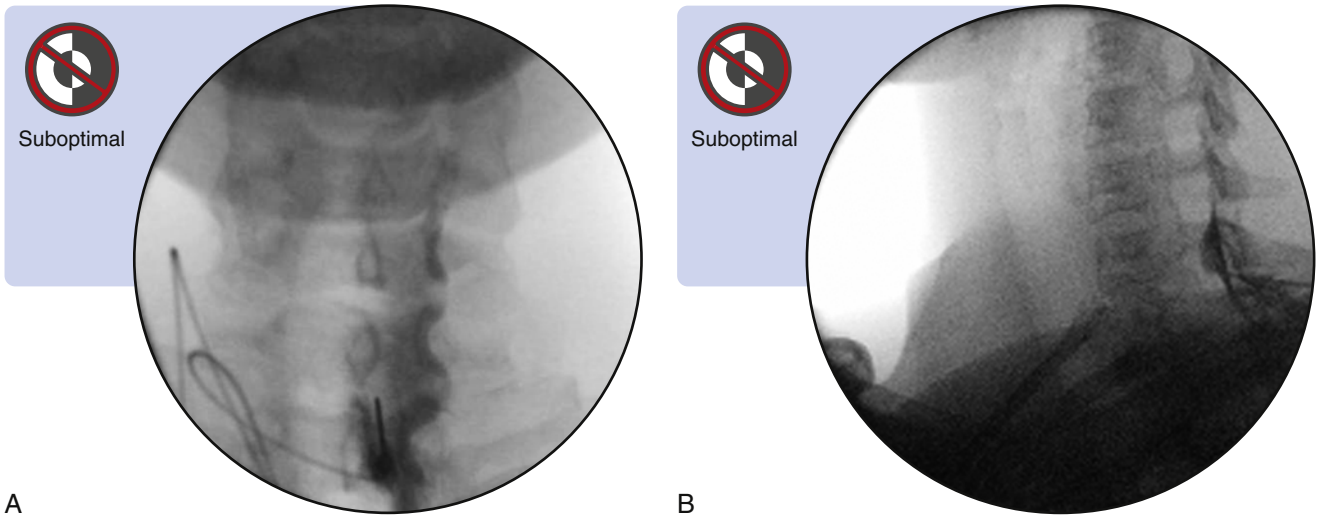


Fig. 25.9. A, Anteroposterior (AP) view of a suspected subdural injection. Note contrast flow has sharp borders as compared to typical epidural flow. **B**, Lateral images of suspected subdural flow. We suggest repositioning of the needle in cases of subdural flow (Courtesy of David Levi, MD). See Chapter 12, Lumbar Interlaminar ESI, for further discussion.

Video 25. Video of a cervical IL-ESI with inadvertent vascular injection.

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CHAPTER 26

Cervical Spinal Cord Stimulation

Ruby E. Kim and Michael B. Furman

Spinal cord stimulation was previously used as a "last resort" for patients who no longer had any other treatment options; however, it should be considered sooner in the treatment armamentarium. It is typically used for patients who have undergone prior cervical surgery with continuous upper limb radicular pain or for patients with upper limb complex regional pain syndrome. It is best advised for patients with more appendicular pain as opposed to axial pain. In Europe, spinal cord stimulation has been described for the treatment of vascular claudication and angina.

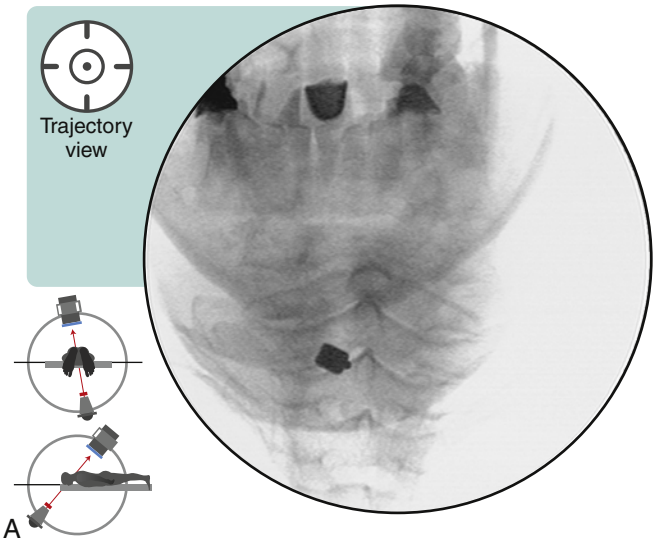
The technique described in this chapter follows the algorithm described elsewhere in this book. In particular, we use a trajectory view to identify the oblique and tilt angle (i.e., the entry point) for needle placement. Note that the needle entry angle is as shallow as possible so that the stimulator lead will smoothly exit the needle into the posterior epidural space, passing along the patient's midline until the active electrodes reach the level at which the patient's pain symptoms are covered, which is often at the upper cervical levels, as high as C2. To obtain that smooth exit, the introducer needle should have a shallow angle trajectory relative to the patient (i.e., to be as parallel to the patient's body as possible). Because we are using the trajectory, contralateral oblique (CLO), and lateral safety views, it is not necessary to step off the lamina with the following described technique.

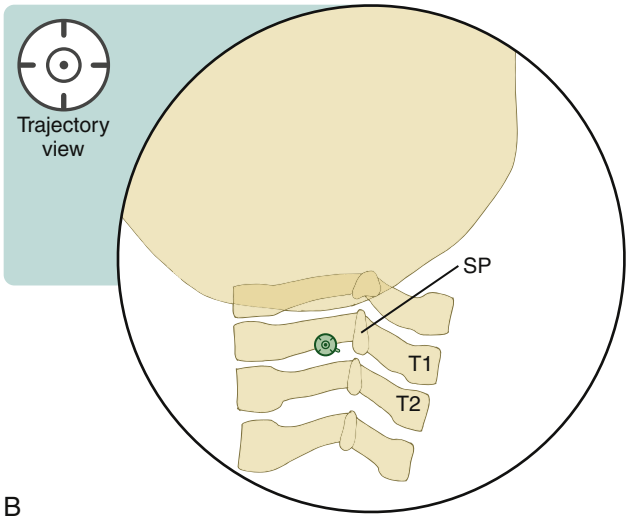
Access to the cervical dorsal epidural space may be obtained with interlaminar access, entering at levels between C7-T1 and T2-T3.

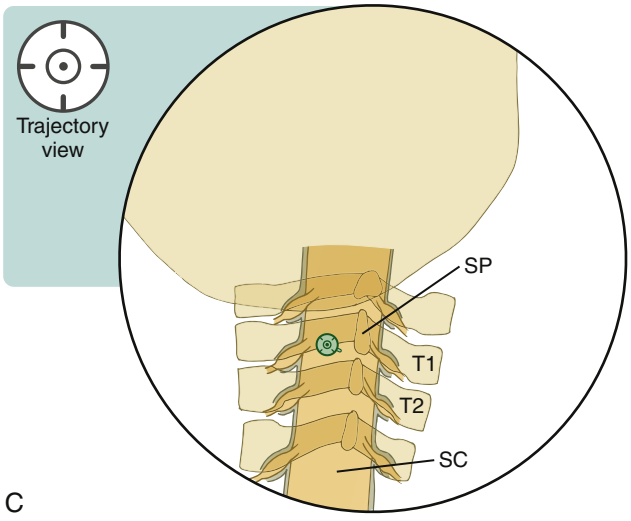
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 26.1)

- Confirm the appropriate interlaminar space with the anteroposterior (AP) view. (We demonstrate T1-T2 here.)
- Tilt the C-arm image intensifier as caudally as possible to still allow access to an open interlaminar space.
- Slightly oblique the C-arm contralateral to the symptomatic side so that the introducer will be set up to help guide the stimulator lead. The lead will have a tendency to travel contralateral to the side of entry, thereby making this technique an efficient method for facilitating proper lead positioning.
- Anesthetize the skin over the interlaminar space (T1-T2 demonstrated here), and use an 18-G, 1.5-inch needle to dilate the skin.
- Remove the 18-G needle, and use the introducer needle to obtain the trajectory needle view.
- Because this is the trajectory view, the introducer needle entry position should be parallel to the C-arm beam.
- Note that the angle of the introducer needle is as shallow as possible, as described in this chapter's introduction.







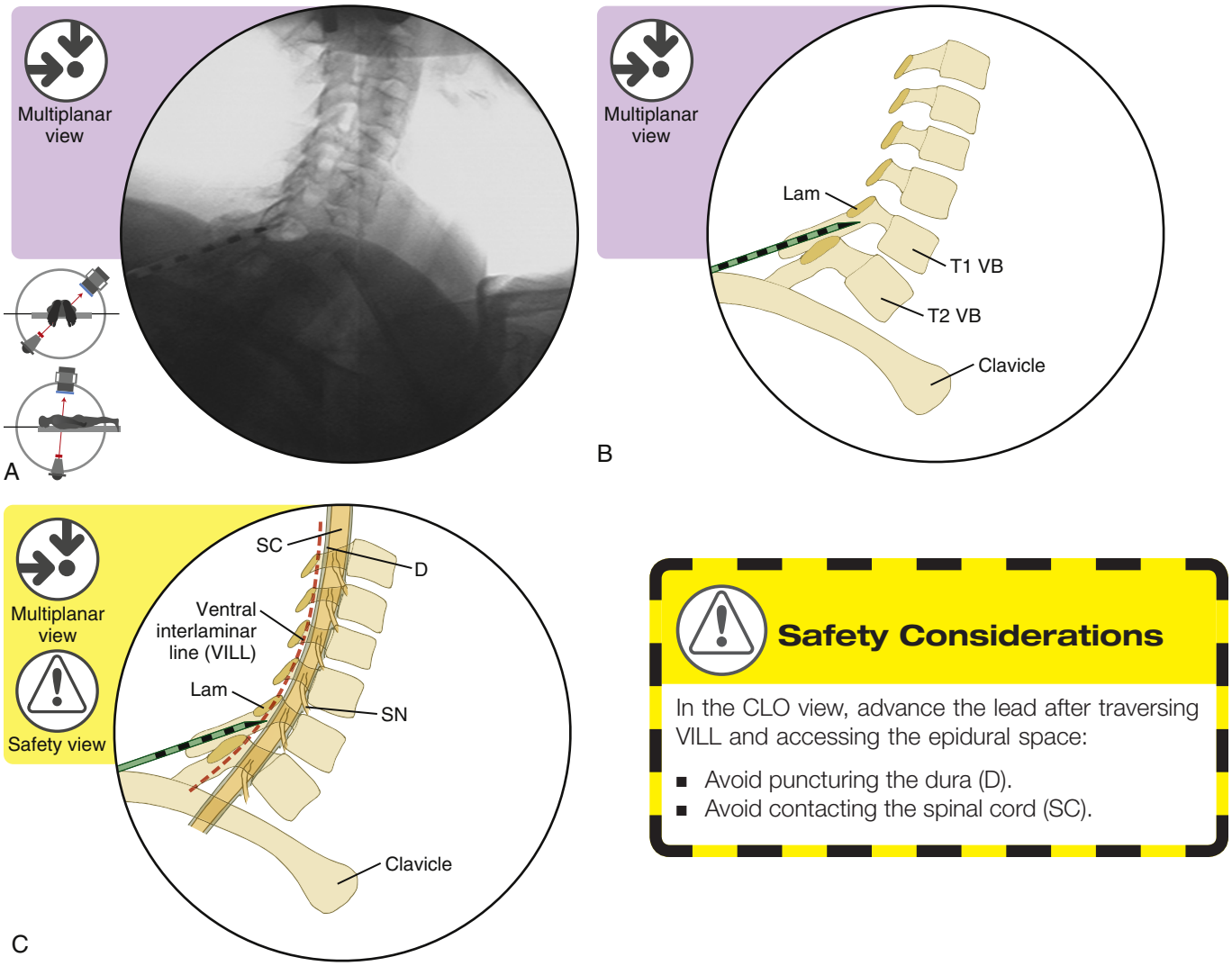
There are typically no other radiolucent structures that are safety considerations in this trajectory view, besides advancing the needle too far ventrally. Please use the other views for needle advancement to best visualize corresponding landmarks.

Fig. 26.1. A, Fluoroscopic image of a trajectory view with the needle tip in position over the T1-T2 interlaminar space. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

- Tilt the C-arm cephalad to confirm that the introducer tip is over the inferior lamina.
- Advance the introducer tip until it approaches the superior edge of the inferior lamina, keeping the tip at the midline. It does not need to touch the periosteum.
- Confirm safety with the CLO view (as discussed in Chapter 3 and shown in Fig. 3.21), a lateral view, or both.
- The needle is advanced safely and efficiently with the use of the lateral and/or contralateral interlaminar oblique view until it reaches the ventral interlaminar line (VILL) in the CLO view or the spinolaminar line in lateral view.
- Perform the loss-of-resistance technique to enter the epidural space; typically air or the lead blank is used because saline can potentially increase impedance (Figs. 26.2, 26.3).
- Confirm that the lead is in the posterior epidural space prior to returning to the AP view.

NEEDLE POSITIONING IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 26.2)



Safety Considerations

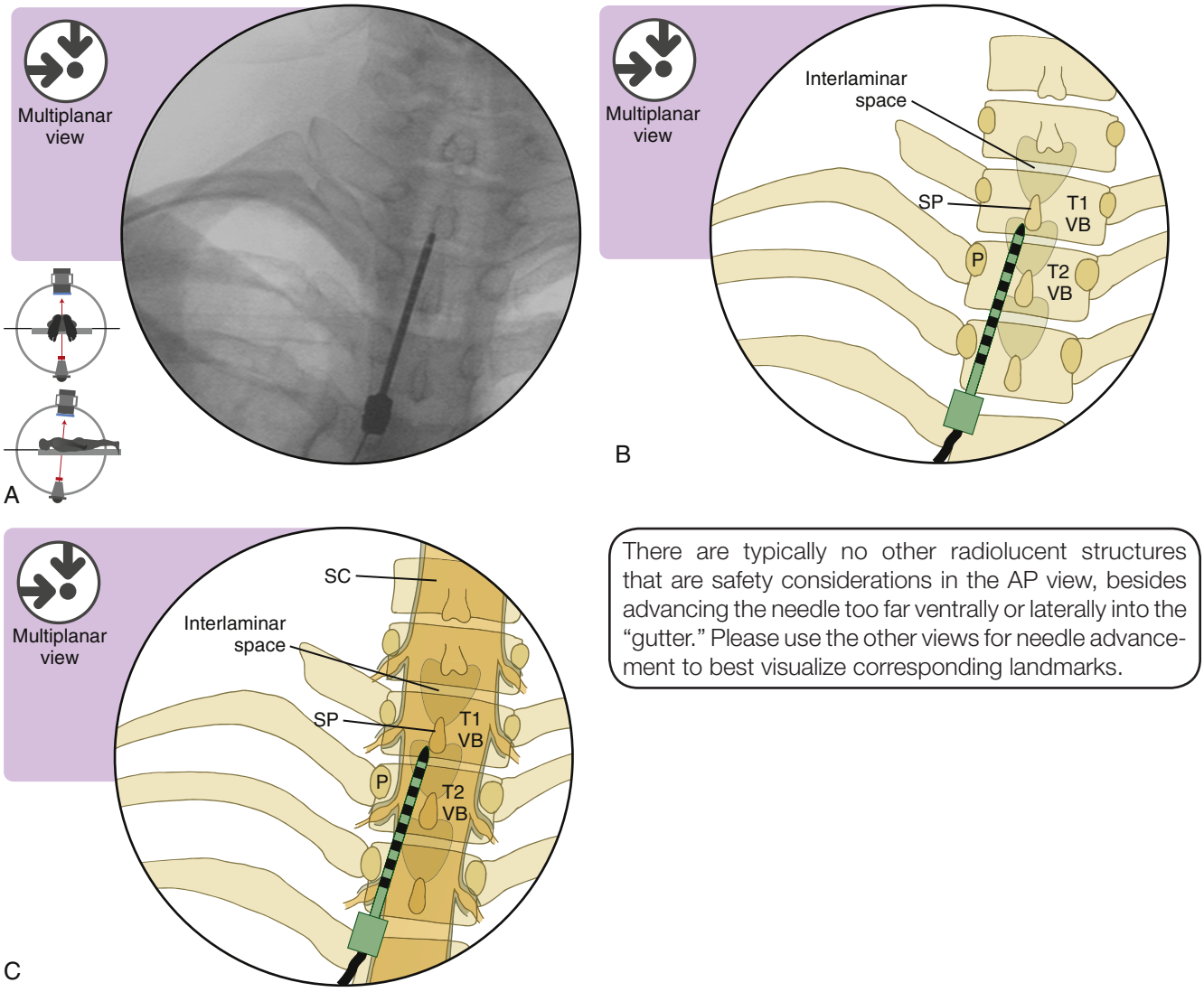
In the CLO view, advance the lead after traversing VILL and accessing the epidural space:

- Avoid puncturing the dura (D).
- Avoid contacting the spinal cord (SC).

Fig. 26.2. A, Fluoroscopic image of the contralateral oblique view with the needle tip in place and the stimulator lead at the needle tip. This view allows for visualization of the lamina (Lam), which will facilitate the visualization of the interlaminar space and ventral interlaminar line (VILL). **B,** Radiopaque structures, contralateral oblique view. **C,** Radiolucent structures, contralateral oblique view. Note that the introducer needle is seen between the laminae (Lam) approaching VILL. The introducer needle's angle should be as shallow as possible. The contralateral oblique view can be used to determine if a more rostral interlaminar approach may be used than the one that had been originally targeted.

NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 26.3)

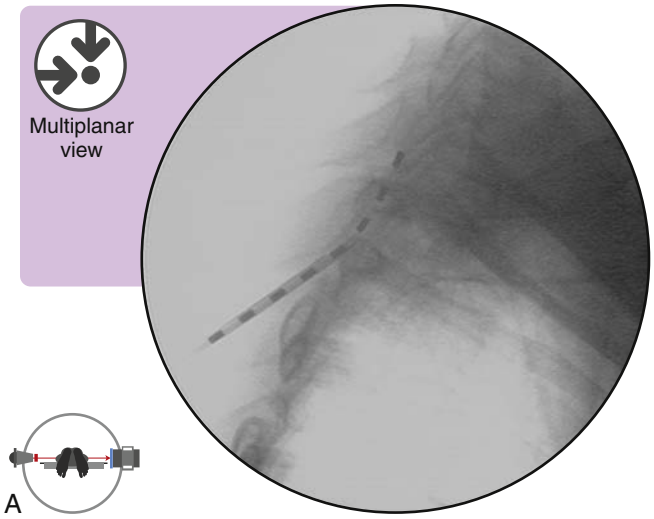
- Start driving the stimulator lead cephalad while maintaining it in the midline until it is close to the final position.
- Remember to use the bevel of the introducer needle to help guide the lead medially and laterally to reach the final target.



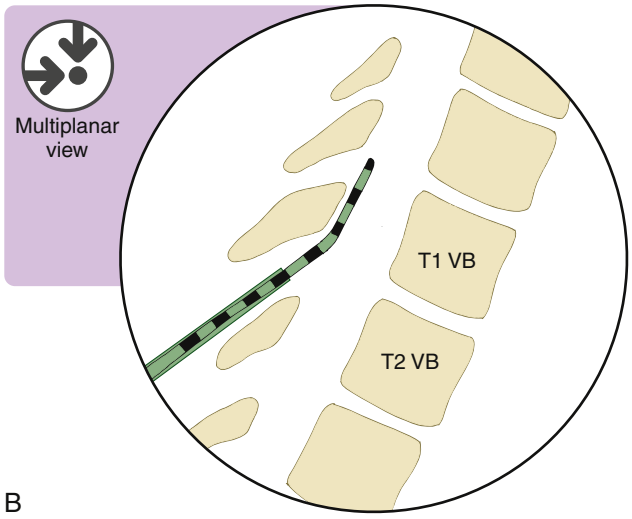
There are typically no other radiolucent structures that are safety considerations in the AP view, besides advancing the needle too far ventrally or laterally into the "gutter." Please use the other views for needle advancement to best visualize corresponding landmarks.

Fig. 26.3. A, Fluoroscopic image of an anteroposterior view with the needle tip as close to the midline as possible and the stimulator lead beginning to advance. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

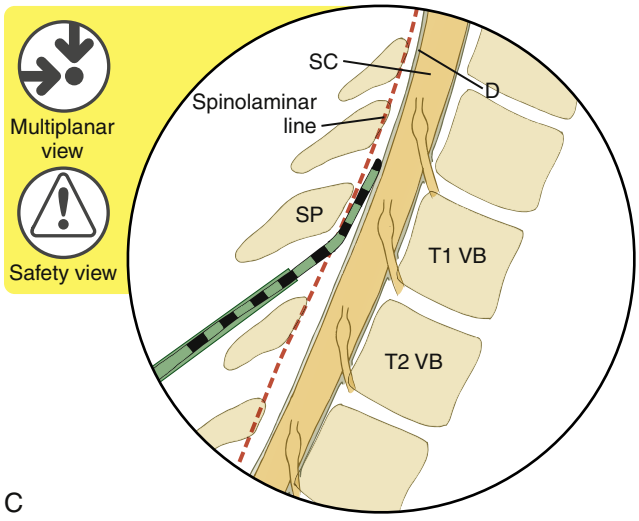
NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 26.4)



A



B



C

Safety Considerations

After traversing the spinolaminar line and accessing the epidural space:

- Avoid puncturing the dura (D)
- Avoid contacting the spinal cord (SC)

Fig. 26.4. A, Fluoroscopic image of the lateral view with the needle tip in place and the stimulator lead beginning to advance. Note the shallow angle of the introducer needle, which allows for a smooth "landing" of the lead into the epidural space with improved stimulator lead manipulation. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Images

Optimal spinal cord stimulator final positioning (Fig. 26.5): We recommend a minimum of two views, including the AP view and either or both of the "true" lateral and CLO views, to confirm final lead positioning.

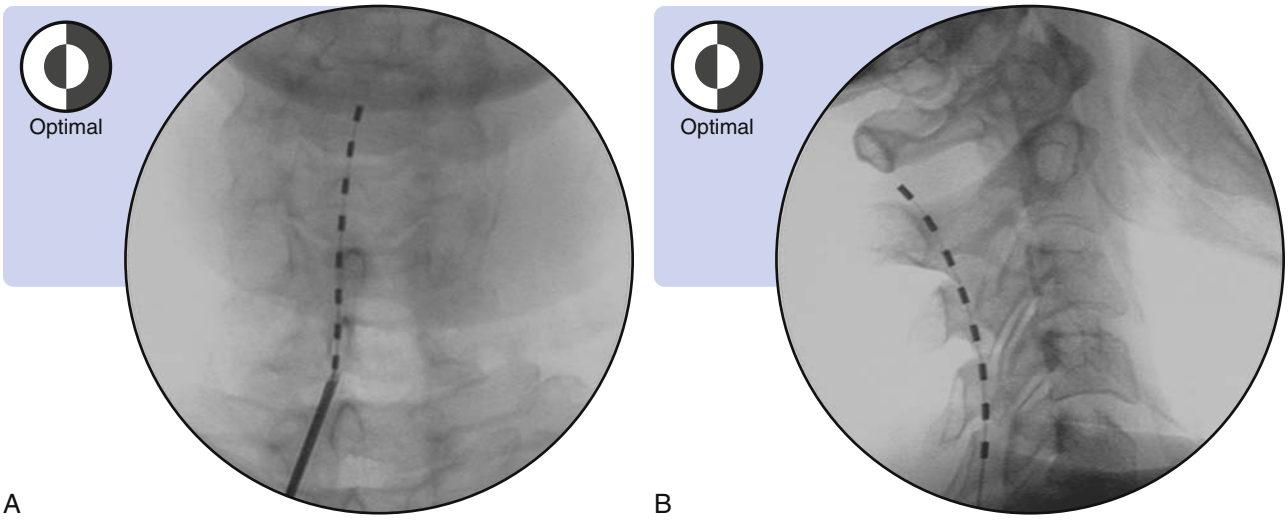


Fig. 26.5. A, Fluoroscopic anteroposterior view with the introducer tip in place and with the stimulator lead being advanced, from left of the midline to C4. **B,** Fluoroscopic lateral view with the stimulator lead in its final position with electrodes spanning from C2 to C5.

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CHAPTER 27

Cervical Transforaminal Epidural Steroid Injection

Ruby E. Kim, Isaac Cohen, and Michael B. Furman

Cervical transforaminal epidural steroid injections are indicated to relieve radicular symptoms with or without axial neck pain from cervical nerve root irritation. The traditional approach to the epidural space was interlaminar. Transforaminal epidural steroid injections are used to deliver the injectate to the ventral epidural space where the pain generators are located: the posterior annulus, ventral aspect of the nerve root sleeve, and intervertebral neural foramen.

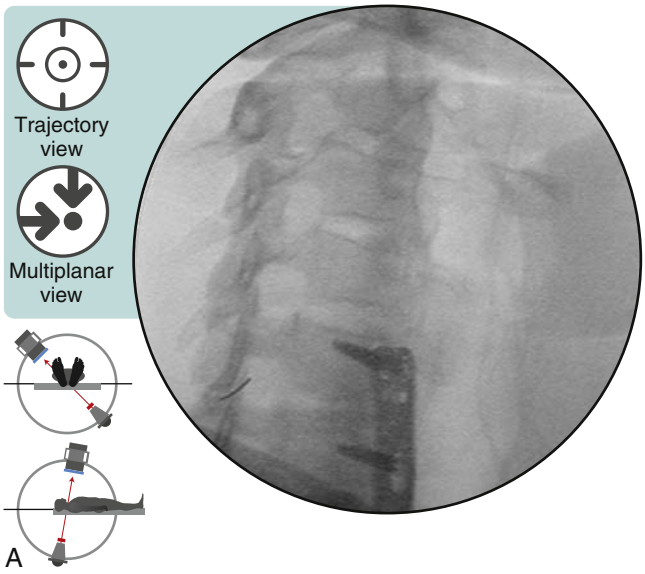
Neurovascular risks for this procedure are high, with known complications thought to be caused by the intravascular injection of a particulate steroid, thereby resulting in the embolism of vascular structures with infarction. Digital subtraction is strongly advised to increase sensitivity in the detection of vascular contrast flow. Note that the trajectory (oblique) view is also one of the multiplanar views. This procedure may be performed in the supine position as demonstrated in this chapter or in the lateral decubitus position.

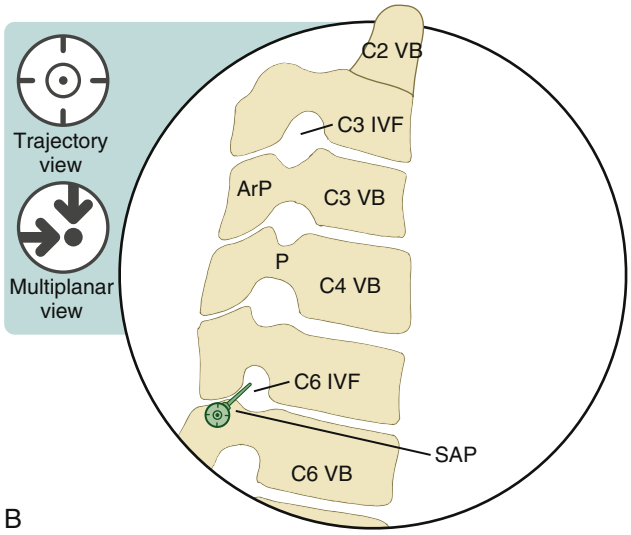
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

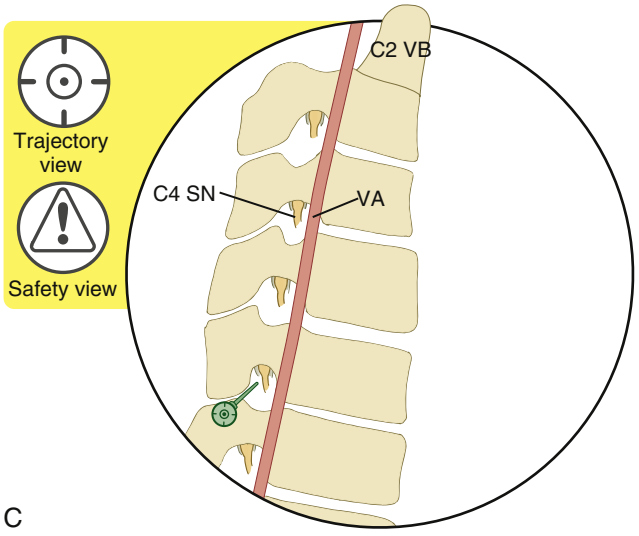
Trajectory View (Fig. 27.1)

The Trajectory View (Foraminal Oblique) Is Also a Multiplanar View

- The patient is positioned supine. Rotation of the chin to the contralateral side can be used to expose the ipsilateral neck.
- Obtain a posteroanterior (PA) view.







Safety Considerations

It is imperative that the needle tip be located at the dorsal aspect of the IVF to avoid vertebral artery puncture.

Fig. 27.1. A, Fluoroscopic image of the trajectory view with the needle stepping off the superior articular process (SAP) into the dorsal aspect of the foramen. The initial target was the SAP, and the needle was subsequently advanced into the foramen. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

- **Oblique the C-arm image intensifier** approximately 45 degrees toward the symptomatic side (the right side, in this case) to optimally maximize the size of the intervertebral foramen (IVF).
- The most rostral IVF is C3 (C2-C3). **Count downward from the C3 (C2-C3) IVF to identify the targeted IVF.**
- **Tilt the C-arm image intensifier** to square off the superior end plate closest to the targeted IVF.
- Adjust the obliquity and the tilt to **optimally enlarge the size of the targeted IVF.** Obliquity optimizes the antero-posterior width of the IVF, and cephalocaudal tilt optimizes the height of the IVF. A maximally enlarged IVF in height and width confirms that the X-ray beam has been optimally positioned parallel to the targeted root canal.
- The target point is the junction of the inferior/caudal posterior half of the IVF and the superior articular process (SAP) with skin entry over the **SAP.** This angle is used for needle entry and advancement.
- The needle should be advanced parallel to the C-arm beam until it contacts the SAP.
- Once the needle has contacted the SAP, needle advancement is stopped. A PA view (safety view) is obtained to determine the depth of insertion.
- Ultimately, the needle tip destination is the **dorsal aspect of the IVF** to avoid vertebral artery penetration.

Optimal Views in Multiplanar Imaging

After the needle is placed in the trajectory view, use the PA view to confirm that the needle tip has not been placed beyond the midline of the articular pillar (ArP).

OPTIMAL NEEDLE POSITIONING IN THE POSTEROANTERIOR VIEW (FIG. 27.2)

- In the PA view, the needle is advanced until the tip reaches the midline of the ArP, midway between the lateral margin of the articular pillar and uncinate process.
- Inject the contrast medium under real-time fluoroscopy in PA view, using digital subtraction mode if available.

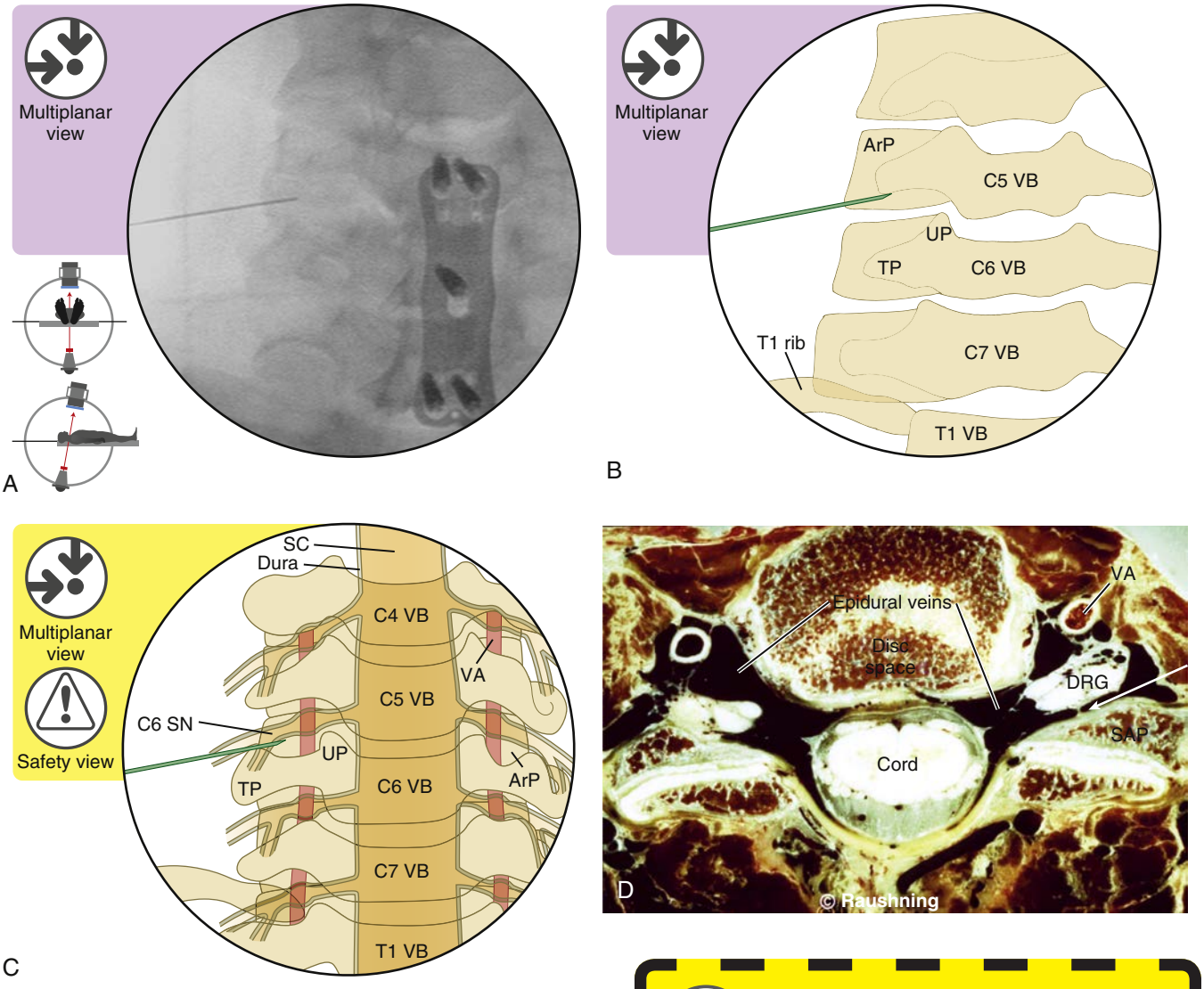


Fig. 27.2. A, Fluoroscopic image of the posteroanterior view with the needle tip approaching the articular pillar midpoint. **B,** Radiopaque structures, posteroanterior view. **C,** Radiolucent structures, posteroanterior view. **D,** Axial cut demonstrating the anatomy. Note the association of the needle, dorsal root ganglion (DRG), and vertebral artery (VA). (*From Rauschning W. Cryosectional imaging of spinal anatomy, <http://www.spineuniverse.com/author/985/rauschning>; 2000 [accessed 05/27/17].*)

Safety Considerations

Avoid dural sleeve and spinal cord puncture: It is imperative that the needle tip not be advanced beyond the midline of the articular pillar.

Table 27.1 Patient Safety Considerations for Cervical Transforaminal Epidural Steroid Injections

Suggestions	Rationale
Single-level unilateral injection	Minimizes the odds of complications
Multiplanar imaging	Localizes the needle tip safely (i.e., in the dorsal foramen, lateral to the lateral mass center)
Short-bevel needle	Less chances of shearing
Unbent needle	Less chances of shearing; should needle rotate in the tissue
Extension tubing	Less adjustment of needle
Needle hub primed with contrast	Less chances of intravascular air injection
Live contrast	Better for observing intravascular injection, if present
Live digital subtraction	Best for observing intravascular injection, if present
Lidocaine test dose with 90-second observation	Intraarterial lidocaine may result in seizure activity that is reversible, whereas an infarct is irreversible Vascular anesthetic penetration may cause ringing in ears, metallic taste, etc.
Nonparticulate steroid (e.g., dexamethasone)	Minimizes the risk of particulate embolization

NEURAL VERSUS VASCULAR SAFETY: A TRADE-OFF

A cadaveric dissection study by Huntoon revealed that 22% of the ascending and deep radicular arteries were located proximal to the external opening of the cervical IVF.

One third of the ascending and deep cervical arteries were noted to supply the anterior spinal artery via feeder radicular or segmental medullary arteries.

These findings suggest that positioning the needle tip at a deeper location (between the midpoint of the lateral mass and uncinate process) might diminish the chance of encountering a radiculomedullary artery. However, with this deeper needle placement, misinterpretation of a true AP view could conceivably lead to puncturing of the thecal sac or spinal cord.

Thus, in favor of neural safety, the needle tip should not be advanced beyond the lateral mass midpoint on the PA view. The reader is referred to Table 27.1 for multiple vascular safety recommendations.

Multiplanar imaging is obtained for the final confirmation of the needle tip's position before the flow is visualized with the contrast.

See Table 27.1 for techniques to minimize risk.

HOURGLASS CONCEPT (FIG. 27.3)

When seen in the cross section, the cervical IVF is shaped like an hourglass due to its external and internal openings and narrow waist (Fig. 27.3A). The bony edges of the cervical IVF seen on the foraminal oblique view represent the narrow waist of the cervical intervertebral foraminal canal and not the external opening of the foraminal canal (Fig. 27.3B). Awareness of this three dimensional configuration will diminish risk of overpenetration with needle advancement in the trajectory view.

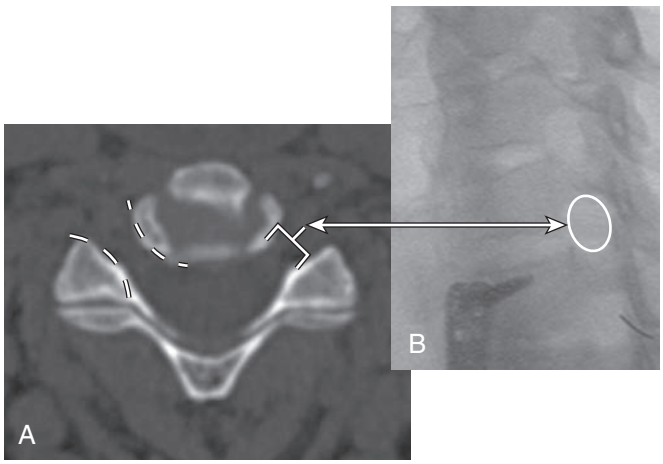


Fig. 27.3. A, Axial computed tomographic (CT) section through the cervical foraminal canal demonstrating its hourglass configuration highlighted with dashed white lines. Compare with the anatomic cross section in Figure 27.2D. **B,** The foramen seen in the foraminal oblique view fluoroscopically represents the narrow waist of the cervical foraminal canal.

Optimal Views (Figs. 27.4 to 27.6)

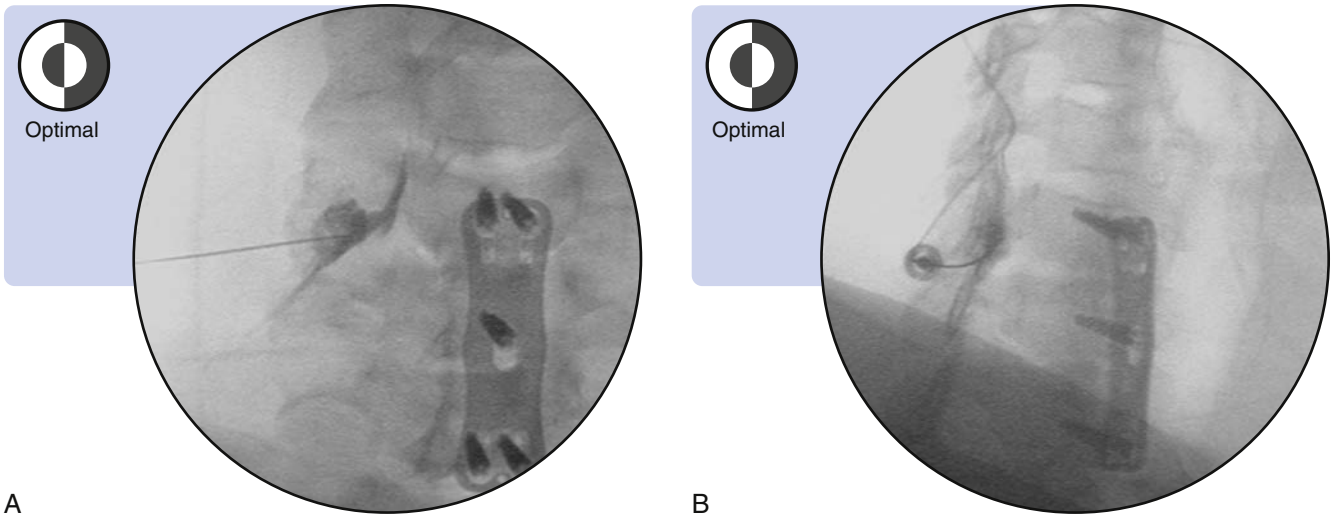


Fig. 27.4. A, Fluoroscopic image of a posteroanterior view of the patient shown in Figure 27.2, with contrast flow around the pedicle. **B,** Fluoroscopic image of a foraminal oblique view of the patient shown in Figure 27.2, with the contrast flow through the IVF extending superiorly and inferiorly.

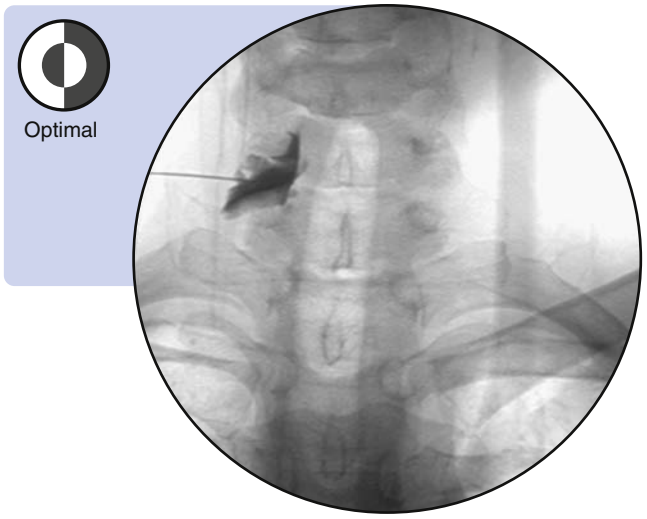
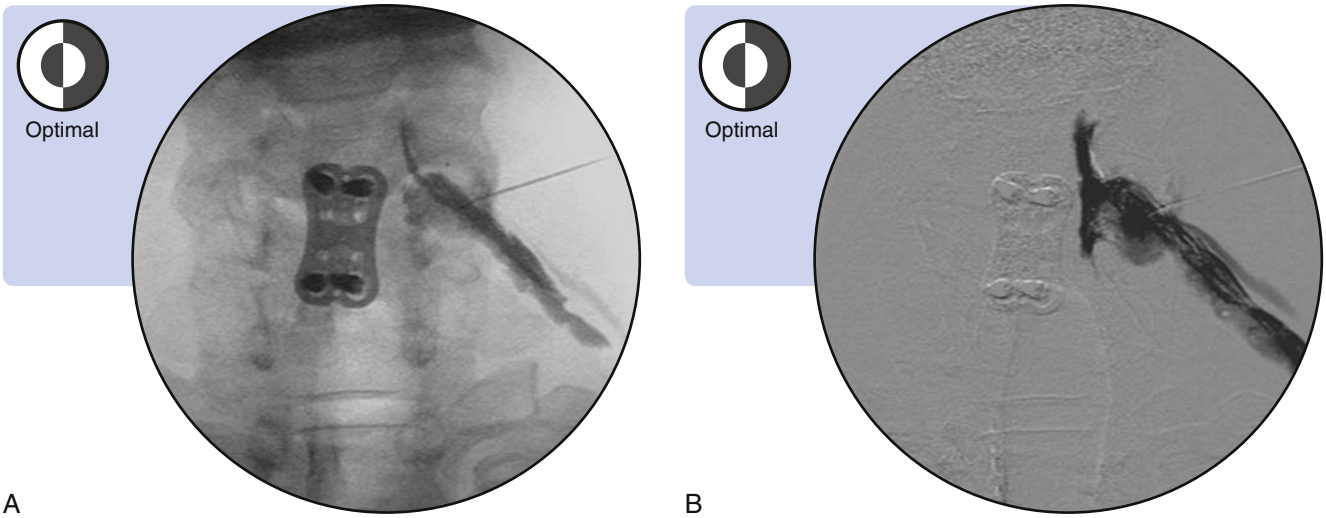


Fig. 27.5. Fluoroscopic image of a posteroanterior view with contrast flow around the pedicle.



A B

Fig. 27.6. A, Fluoroscopic image of a posteroanterior view with contrast flow around the pedicle. Contrast also flows along the exiting spinal nerve more than desired. However, needle repositioning may result in suboptimal epidural flow. **B,** Fluoroscopic image of a posteroanterior view using digital subtraction with contrast flow around the pedicle and exiting spinal nerve.

Suboptimal Views (Figs. 27.7 to 27.9)

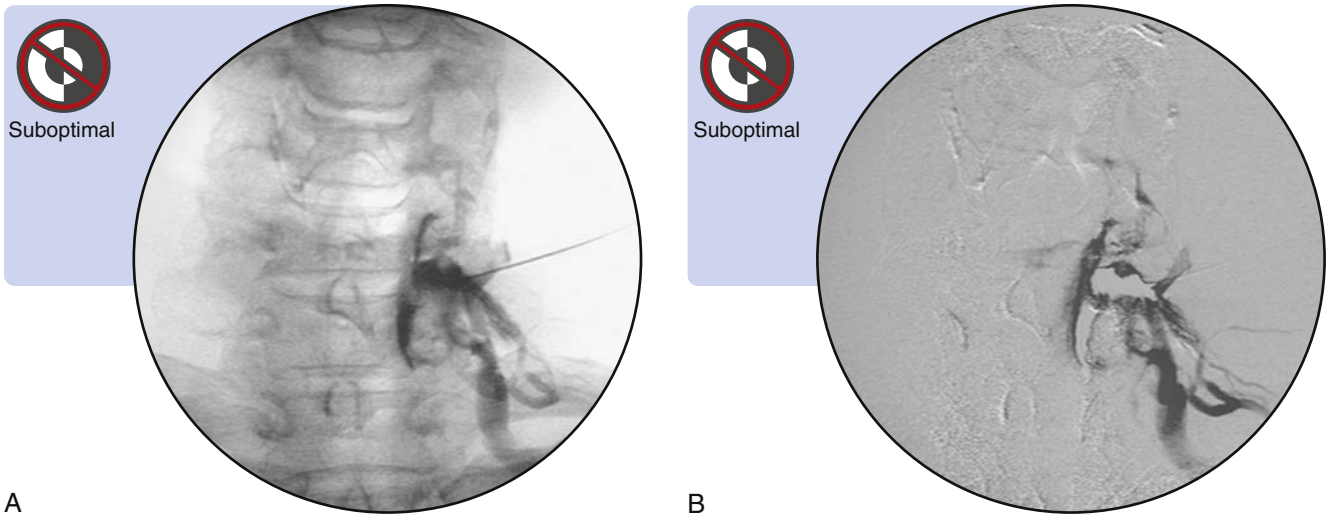


Fig. 27.7. Fluoroscopic images of **A,** a conventional fluoroscopy posteroanterior view and **B,** a digital subtraction posteroanterior view. Both **A** and **B** clearly demonstrate vascular uptake. Although these images are static, when observed under live fluoroscopy, the contrast rapidly dissipates.

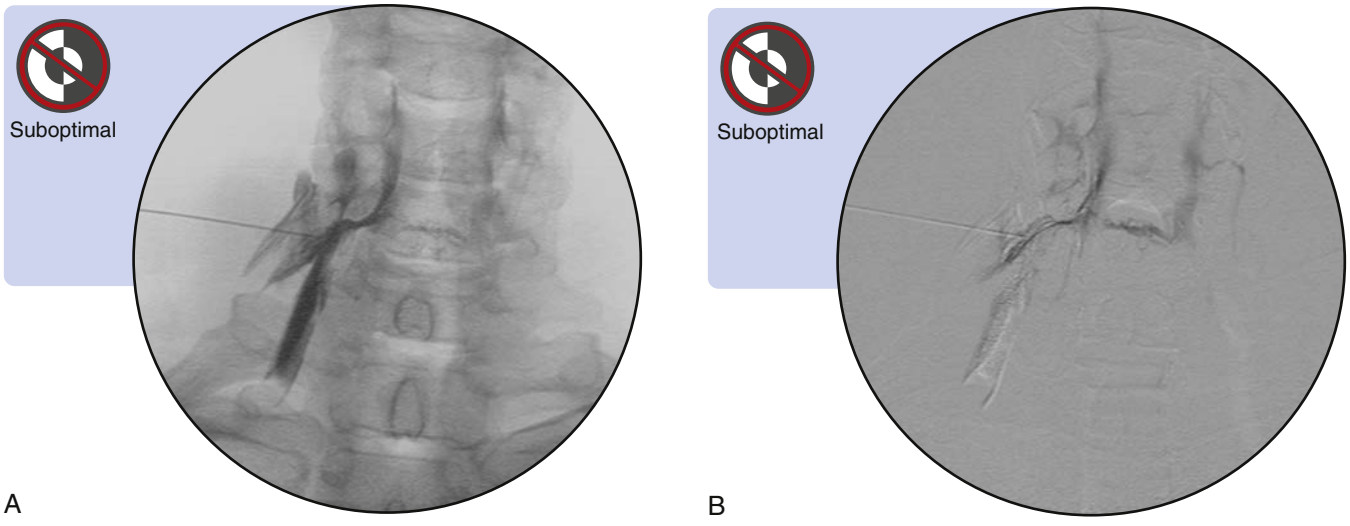


Fig. 27.8. Fluoroscopic images of **A,** a conventional fluoroscopy posteroanterior view and **B,** a digital subtraction posteroanterior view that demonstrates subtle vascular uptake. Digital subtraction demonstrates a horizontal vascular structure and contralateral filling that is barely recognized with conventional fluoroscopy. Although these images are static, when observed under live fluoroscopy, the contrast rapidly dissipates.

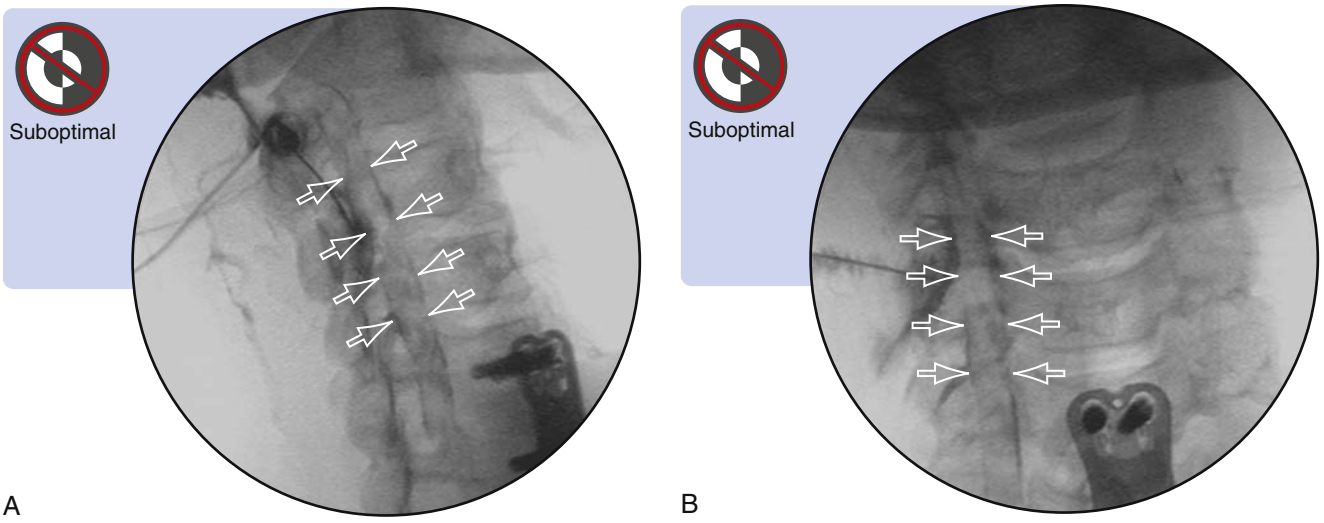


Fig. 28.9. Fluoroscopic images of **A,** a foraminal oblique view and **B,** a posteroanterior view demonstrating the outline of the vertebral artery (open arrows). Although these images are static, when observed under live fluoroscopy, the contrast did not dissipate; thus, demonstrating that this was not an intravascular injection. Instead, the contrast spread along the outer adventitial or intramural layers of the vessel.

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Suggested Readings

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Xu R, Robke J, Ebraheim NA, Yeasting RA. Evaluation of cervical posterior lateral mass screw placement by oblique radiographs. *Spine (Phila Pa 1976)*. 1996;21(6):696–701.

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CHAPTER 28

Stellate Ganglion Injection

Stellate ganglion blocks are used for the treatment of a variety of painful medical conditions that range from sympathetically mediated pain and postherpetic neuralgia in the upper limb, head, and neck region to pain that is associated with intractable angina and posttraumatic stress disorder.

Historically, anesthetic alone has been injected at the C6 vertebral level because prominent landmarks such as the C6 anterior tubercle (i.e., Chassaignac's tubercle), the cricoid cartilage, and the carotid artery have been used when performing landmark-guided injections. A C7 approach has also been described. Both levels are considered acceptable in current practice. However, given the higher risk of pneumothorax and vertebral artery puncture at the C7 level, the C6 level has become the more common approach used by practitioners. Therefore, we recommend an image-guided, contrast-enhanced injection prior to injecting the local anesthetic to ensure proper inferior contrast flow to the stellate ganglion with nonvascular uptake. Furthermore, a hybrid fluoroscopic plus ultrasound-guided approach further enhances the safety of this procedure by confirming optimal contrast flow and avoiding penetration of crucial structures (i.e., the esophagus, jugular vein, and thyroid arteries).

Clinical signs and symptoms that suggest a successful block include the immediate development of Horner's syndrome (see Figure 28A.5); ptosis (i.e., drooping of the upper eyelid from a loss of sympathetic innervation to the superior tarsal muscle); miosis (i.e., constricted pupil); anhidrosis (i.e., decreased sweating on the affected side of the face); and a stuffy nose and increased facial and upper limb temperature on the ipsilateral side within 5 minutes of the procedure (i.e., Guttman's sign). Occasionally, conjunctival redness and unilateral facial flushing may also be observed. A change in heart rate is not a reliable indicator of a successful block. A decrease in pain will also typically accompany a successful block. Ideally, patients should have therapy scheduled immediately after the procedure for functional reassessment and aggressive treatment.

The stellate ganglion is composed of the inferior cervical ganglion (C7) and proximal thoracic ganglion (T1), which are fused together in 80% of the general population. This location is usually anterior to the neck of the first rib, and it extends into the interspace between the C7 and T1 vertebral bodies. If elongated, it may rest on the anterior tubercle of C7. If the ganglia are not fused, the individual ganglia are usually anterior to the neck of the first rib and adjacent to the anterior C7 tubercle. In this situation, the proximal thoracic ganglion is considered to be the stellate ganglion.

Contraindications are similar to those of other interventional spine procedures, with a few notable additions, including cardiac conduction block and the risk of bullous puncture in patients with severe emphysema. Only one side should be injected per session. Bilateral injections can result in unwanted vascular responses. A commonly encountered side effect is recurrent laryngeal nerve block, which can cause stridor and difficulty swallowing.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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CHAPTER 28A

Stellate Ganglion Block: Fluoroscopic Guidance

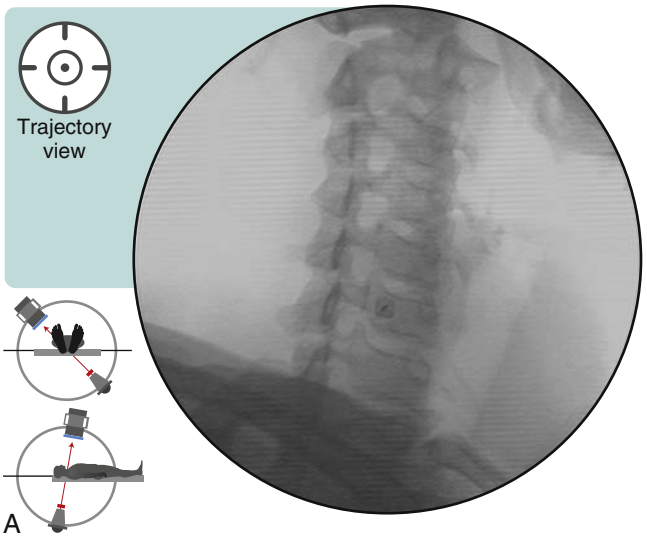
Kermit W. Fox and Michael B. Furman

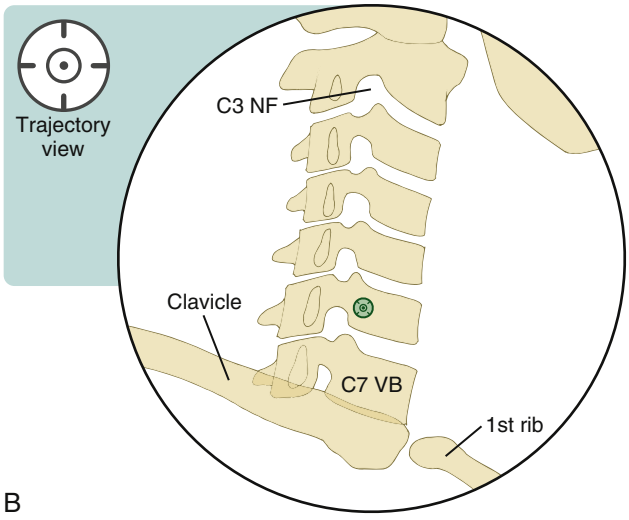
Contrast injected at the C6 level has consistently reached the C7-T1 interspace, which is the commonly accepted location of the stellate ganglion. Ideal injectate spread should extend inferiorly to T2 for upper limb symptoms. The anterior (foraminal) oblique approach is advantageous over the traditional (i.e., paratracheal) approach because it provides an unobstructed trajectory view (i.e., it does not require pushing vascular structures out of the way and radiating the interventionalist's hands).

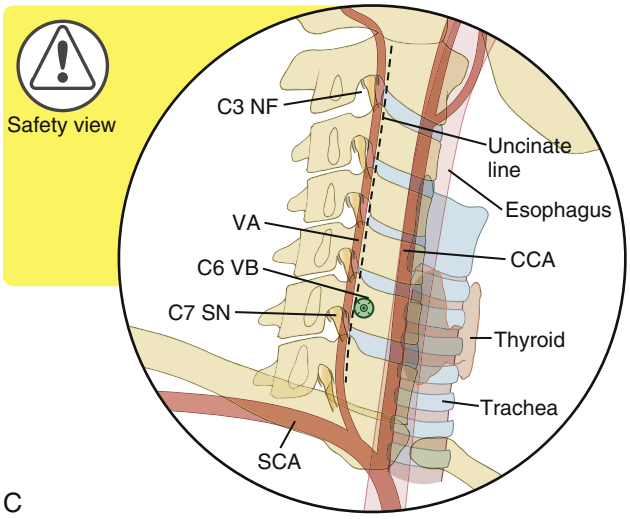
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 28A.1)

- The patient is placed in a supine position.
- Using the posteroanterior view, confirm the C6 level by counting cephalad from T1.
- Tilt the C-arm image intensifier to line up the superior C6 vertebral end plate of the targeted vertebral body (see Chapter 3).
- Oblique the C-arm image intensifier ipsilaterally to obtain a foraminal oblique view (see Chapter 3). With this trajectory view, count down from the most cephalad C3 neural foramen (NF) (AKA C2-C3 NF) to confirm the level of the C6 vertebral body.
- The targeted structure, which is the junction of the vertebral body and the uncinate process (at or slightly medial to the uncinate line), can then be optimally visualized.







Trajectory View Safety Considerations (Figure 28B.1E shows an axial view)

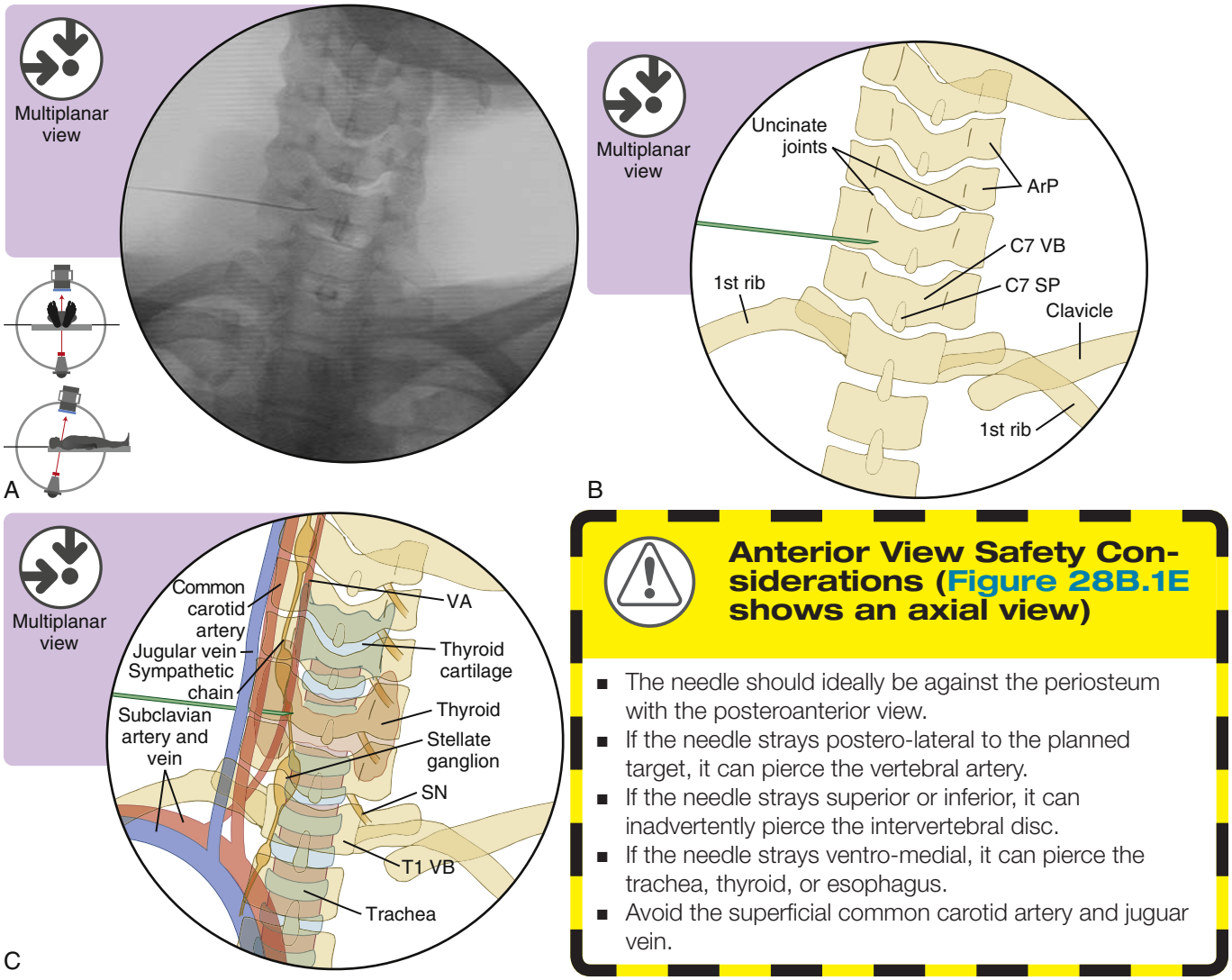
Remain directly over the vertebral body and at or slightly medial to the uncinate line to avoid the:

- Vertebral artery and spinal nerves dorsally.
- Trachea, thyroid, and esophagus, venro-medially.
- CCA and internal jugular ventrally.
- Subclavian artery caudally.
- Intervertebral discs cephalad and caudally.

Fig. 28A.1. A, Fluoroscopic image of the trajectory view with the needle tip in position at or slightly medial to the uncinate line at the junction of the uncinate process and the vertebral body. Because this is the trajectory view, the needle entry position should be parallel to the C-arm beam. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Views in Multiplanar Imaging

OPTIMAL NEEDLE POSITIONING IN THE POSTEROANTERIOR VIEW (FIG. 28A.2)

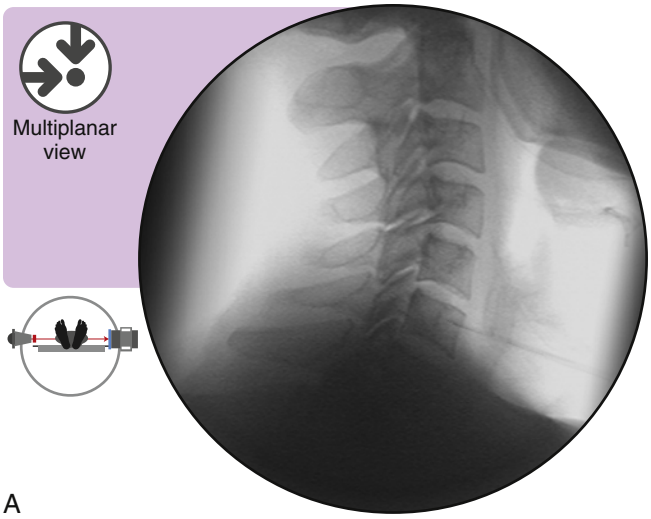


Anterior View Safety Considerations (Figure 28B.1E shows an axial view)

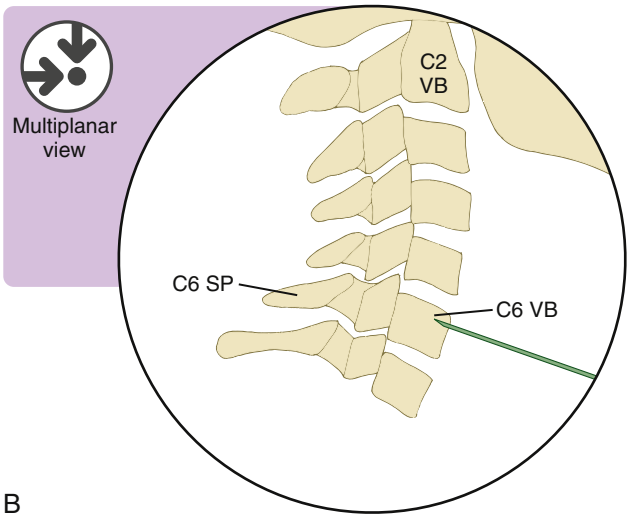
- The needle should ideally be against the periosteum with the posteroanterior view.
- If the needle strays postero-lateral to the planned target, it can pierce the vertebral artery.
- If the needle strays superior or inferior, it can inadvertently pierce the intervertebral disc.
- If the needle strays ventro-medial, it can pierce the trachea, thyroid, or esophagus.
- Avoid the superficial common carotid artery and juguar vein.

Fig. 28A.2. A, Fluoroscopic posteroanterior view with the ideal needle position. Confirm the C6 level by counting cephalad from T1. **B,** Radiopaque structures, posteroanterior view. **C,** Radiolucent structures, posteroanterior view.

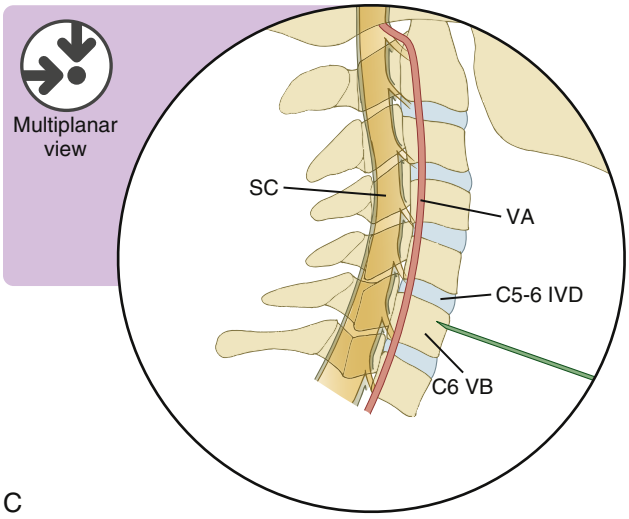
OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 28A.3)



A



B



C

Lateral View Safety Considerations

- If the needle is against the vertebral body periosteum, it is unlikely to get near any vital structures that are posteriorly located.
- The lateral view should be used to confirm that the needle is not inadvertently transdiscal or in the spinal cord before injection.

Fig. 28A.3. A, Fluoroscopic lateral view with the ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

Optimal Views (Figs. 28A.4 and 28A.5)

- When optimal flow has been confirmed with contrast, a small (i.e., 0.5 cc) test dose of local anesthetic (e.g., 1% lidocaine) is injected, and the patient is observed for 60 to 90 seconds to further minimize the risk of intravascular injection.
- Subsequently, if no abnormal symptoms are noted, 10 cc of anesthetic is injected.
- Although larger volumes have traditionally been used for landmark-guided (aka "blind") stellate ganglion blocks, adequate coverage of the stellate ganglion is obtained with this smaller volume of injectate.
- A smaller injectate volume may also decrease the risk of anesthetic-related complications that were discussed in the chapter's introduction.
- For facial and neck issues, flow to C6 or C7 is adequate. For the upper limb, flow inferior to T2 is optimal.

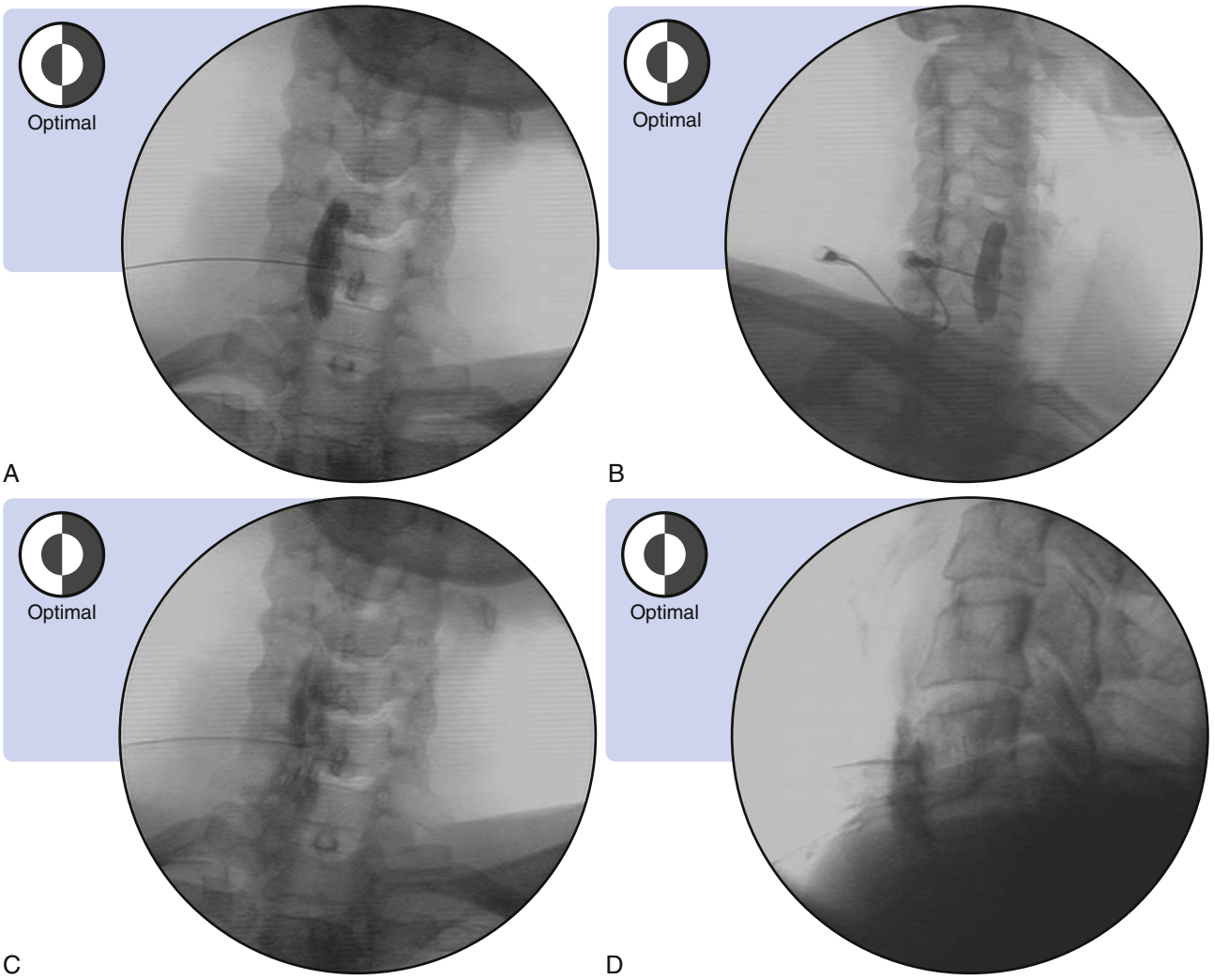


Fig. 28A.4. A, Fluoroscopic image of a posteroanterior view after the injection of 2 cc of contrast. The contrast is tracking vertically along the longissimus colli muscle in the region where the sympathetic trunk is known to reside. **B,** Fluoroscopic image of a foraminal oblique view after the injection of 2 cc of contrast. **C,** Fluoroscopic image of a posteroanterior view of the same patient after slowly injecting 5 cc of anesthetic into the ganglion. Note the cephalad flow of contrast to the C4-C5 interspace and the caudad flow to the first thoracic segment. **D,** Fluoroscopic image of a lateral view of a different patient after slowly injecting 5 cc of anesthetic into the ganglion.

Fig. 28A.5. Horner's syndrome in a patient after right stellate ganglion block. Note the ptosis and miosis on the patient's right side.

CHAPTER 28B

Stellate Ganglion Injection: Ultrasound Guidance

Christopher Bednarek, Paul S. Lin, Jonathan S. Kirschner, and Michael B. Furman

For ultrasound (US), a transverse in-plane with long-axis confirmation technique at the level of the Chassaignac's tubercle of C6 is described. By utilizing a hybrid fluoroscopic approach, US- guidance is used to carefully position the needle away from critical structures in the soft tissue of the anterolateral neck, guiding the safest injection possible. After US-guided (USG) needle placement, injected contrast under fluoroscopy (hybrid technique) verifies unilateral and nonvascular contrast flow. Vital structures identified and avoided under USG injection include the trachea, esophagus, thyroid, inferior thyroid artery, recurrent laryngeal nerve, common carotid artery, internal jugular vein, and vertebral artery.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique

- The patient is placed in a supine position. The patient's head is slightly rotated contralateral to the approached side with minimal cervical extension.
- Place the linear transducer in transverse position over the midline at the cricoid cartilage and scan inferiorly until the inferior aspect of the thyroid is visualized.
- Move the transducer laterally toward the desired side until the anterior aspect of the Chassaignac's tubercle of C6 is identified (Fig. 28B.1B). In this position, visualize the lateral aspect of the thyroid, carotid artery, internal jugular vein, longus colli, and longus capitus muscles. Color or power Doppler may further clarify the positions of vessels. Structures of interest are noted in Figs. 28B.1C, D, E.
- The needle approaches the target from a lateral to medial position aiming anterior to the prevertebral fascia at the ventral aspect of the longus colli muscle, medial to Chassaignac's tubercle. Note that the needle trajectory is actually slightly posterior to anterior as the needle advances medially.
- Choose an in-plane needle trajectory that avoids puncture of critical structures. If critical structures are in the needle trajectory, the transducer can be rotated, to avoid penetration of vessels.

Fig. 28B.1. A, Suggested room, ultrasound unit, and interventionalist setup for injection, Note that the trajectory is actually slightly posterior to anterior as the needle advances medially.

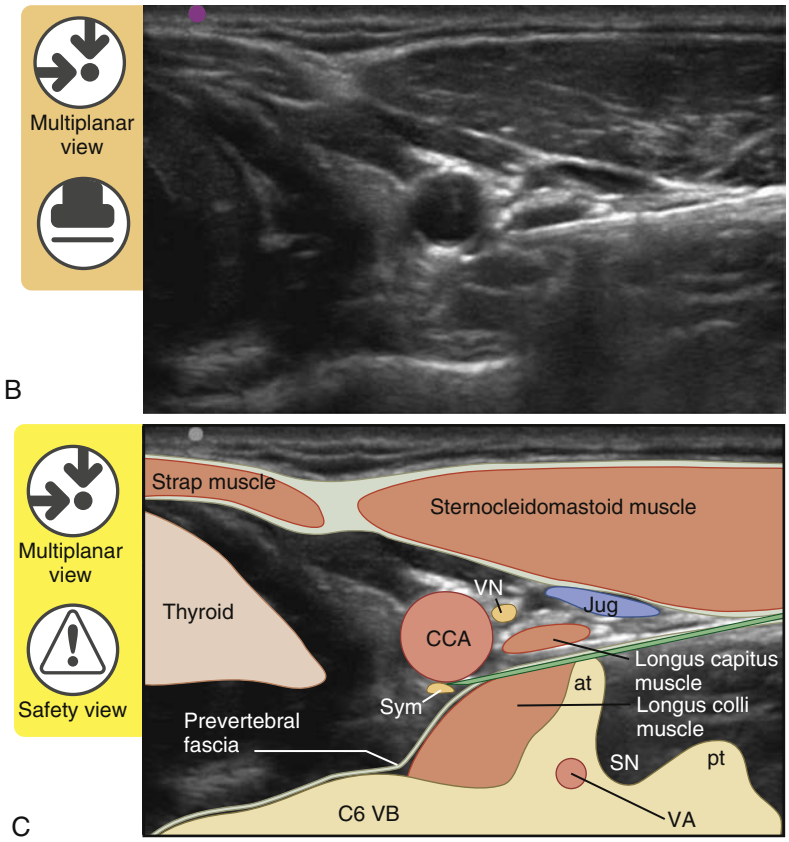
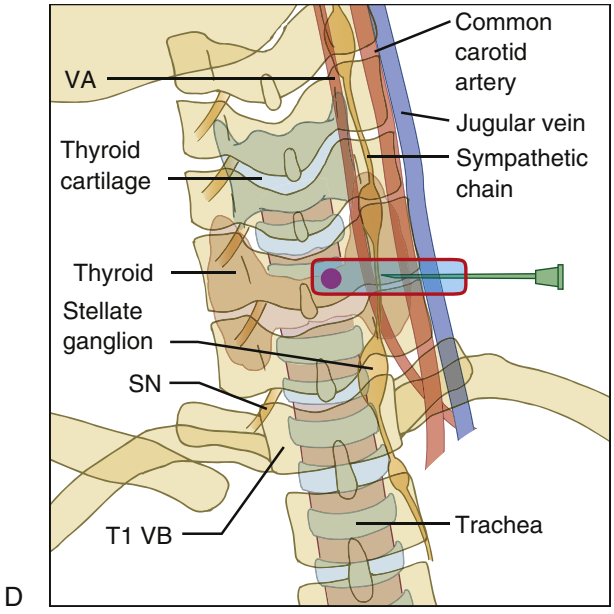


Fig. 28B.1, cont'd B, In-plane ultrasound image of the anterolateral left neck for stellate ganglion block with ideal needle placement. Note safe placement as the needle avoids all vascular structures along its trajectory. **C,** Drawing of important structures overlaid on Fig. 28B.1B. *CCA,* Common carotid artery; *SG,* sympathetic ganglion/chain; *VN,* vagus nerve; *Jug,* jugular vein; *Sym,* sympathetic chain; *VA,* vertebral artery; *SN,* C6 spinal nerve; *at*, anterior tubercle; *pt,* posterior tubercle.



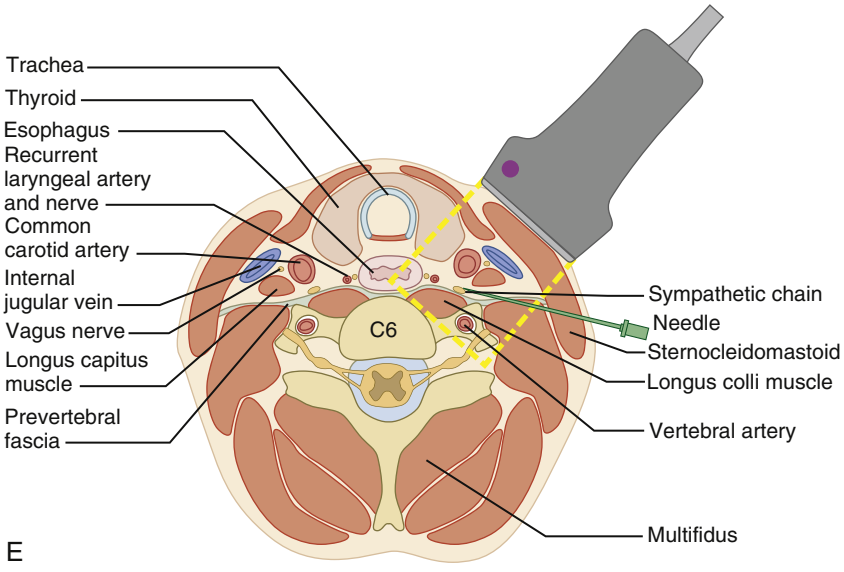


Fig. 28B.1, cont'd D, Proper placement of ultrasound transducer. **E,** Cross section of the neck at the level of C6, ultrasound transducer placement. Note that the trajectory is actually slightly posterior to anterior as the needle advances medially.

In-Plane Technique Safety Considerations

If the angle is too steep, the needle may penetrate the carotid artery or internal jugular vein prior to reaching the target area.
Stay at the level of the Chassaignac's tubercle of C6 to avoid vertebral artery puncture, especially if the transducer drifts inferiorly to the level of C7 where there is an absent (rudimentary) anterior tubercle with an exposed vertebral artery.
Avoid medial structures including the esophagus, trachea, thyroid, and recurrent laryngeal vessels and nerve.
Identify the locations of vascular structures, including the carotid artery, internal jugular vein, external jugular vein, vertebral artery, and inferior thyroid artery by utilizing power or color Doppler.

Out-of-Plane Confirmation

- This view is utilized to visualize the needle tip from a long-axis (longitudinal) transducer position after the needle has been placed from the short-axis (axial) approach.
- After the needle is in a desired position from the in-plane technique, rotate the transducer 90 degrees to obtain an out-of-plane view to re-confirm the needle tip position (Fig. 28B.2A).
- In Figs. 28B.2A, B, identify the longus colli muscle inferior to and the longus capitus muscle just superior to the needle's position. Verify that vascular structures superior to the needle (internal jugular and carotid artery) remain unviolated.
- If the needle tip is satisfactorily placed, proceed to fluoroscopic imaging for further confirmation. Contrast is injected under live fluoroscopic imaging and monitored for vascular flow pattern.

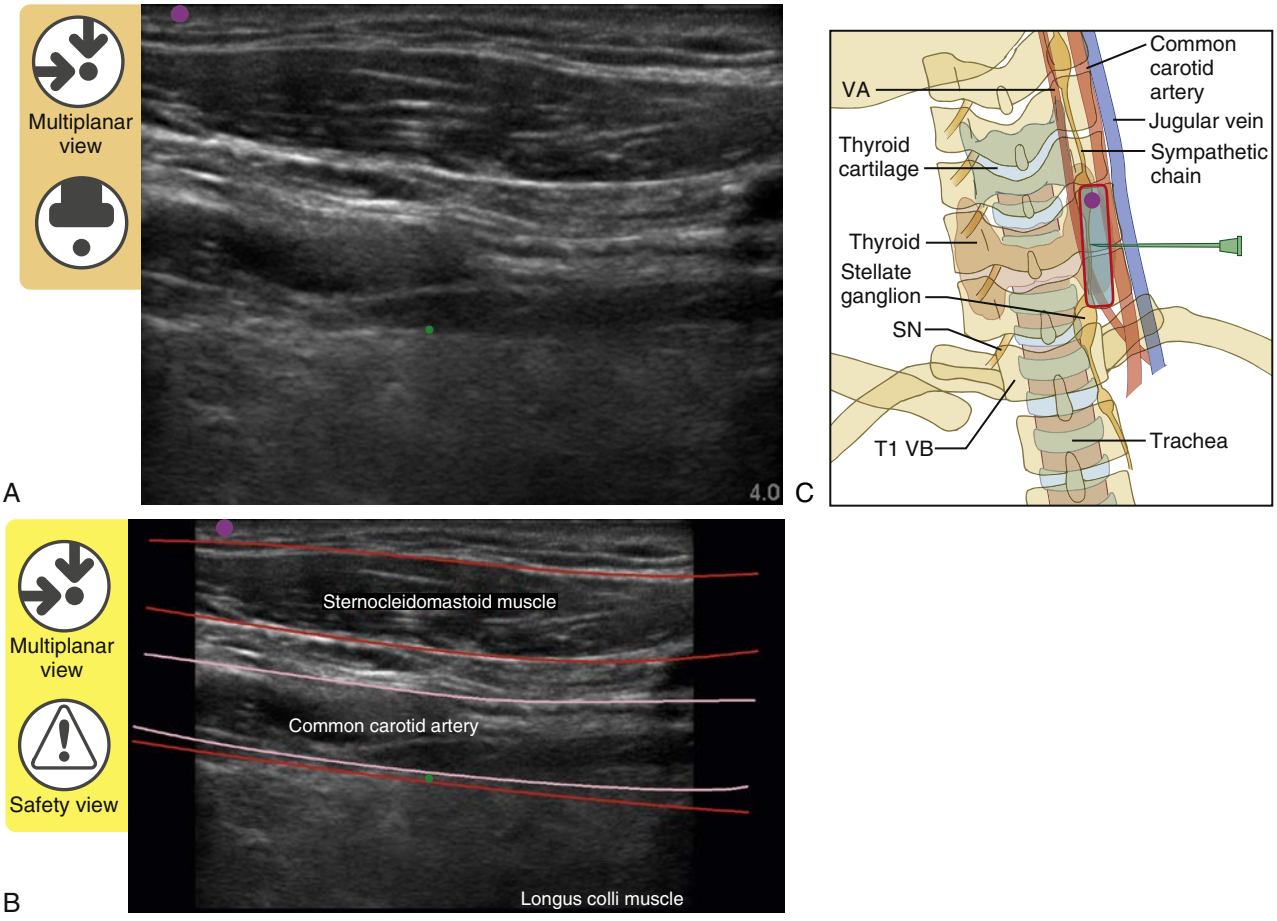


Fig. 28B.2. A, Out-of-plane ultrasound image of the anterolateral left neck for stellate ganglion block with ideal needle placement. **B,** Drawing of important structures overlaid on Fig. 28B.2A. *N,* Needle. **C,** Proper placement of ultrasound transducer.

Out-of-Plane Confirmation Safety Considerations

Please consider the same safety considerations outlined in the In-Plane Technique section, above.

Optimal Image

- Optimal fluoroscopic image of contrast flow after USG stellate ganglion injection demonstrating contrast flow anterior to the prevertebral fascia, surrounding the sympathetic chain at C6 (Fig. 28B.3). Please compare this optimal contrast location and pattern to those visualized in Fig. 28A.4. In the US-guided (USG) technique, the needle trajectory starts more laterally and the injectate flows superficial to the longus colli. In the standard fluoroscopic technique, the target is deeper and along the C6 vertebral body.
- The contrast spreads caudally to the thoracic levels covering the stellate ganglion.

Suboptimal Image

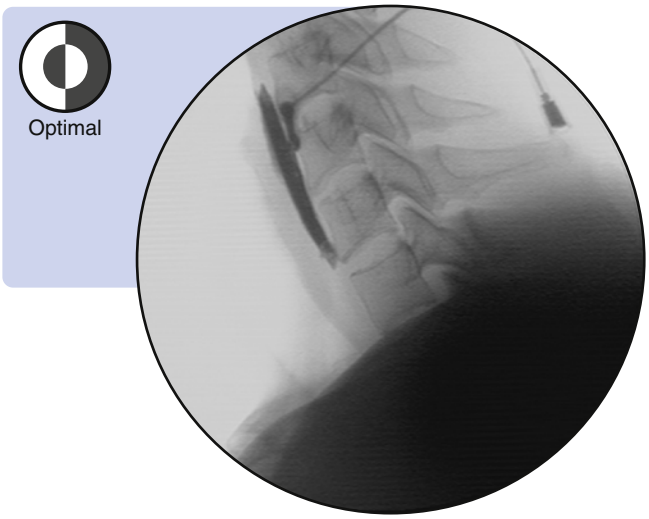


Fig. 28B.3. Fluoroscopic image of a lateral view after injection with 2 cc of contrast. Note that the needle trajectory is actually slightly posterior to anterior as the needle advances medially.

Fig. 28B.4. Simulated out-of-plane needle placement in the common carotid artery.

CHAPTER 29

Cervical Discography/ Disc Access

Thomas S. Lee and Michael B. Furman

Cervical discography was first described in the literature by Ralph Cloward and George Smith in the late 1950s.[1-4] Cervical provocation discography potentially provides a method to obtain pain-generation data with regard to the intervertebral disc.[5] Most importantly, data collection includes pain provocation (i.e., none, discordant, or concordant) correlated with the patient's clinical scenario. Also, it includes contrast volumes and disc architecture (nucleogram, postdiscography computed tomography [CT]). However, the disc architecture is less useful for cervical discography than for lumbar discography. This is based on the normal anatomy of the disc beyond the second and third decades of life.[5,6] During the first and second decades of life, lateral tears may normally occur in the annulus fibrosis before complete ossification. These lateral tears and uncinate fissures may result in the complete transverse splitting of the disc. As a result, the visualization of "normal" nucleogram may be uncommon. Analgesic response is not typically part of the standard cervical protocol, and it has not been readily studied.[7,8]

Over the last 60 years, the usefulness of discography has been closely examined. In this chapter, the scope of the content will not delve into this potential controversy, but the debate does continue through today. When performing discography, the final needle-tip target is the nucleus pulposus, which is the geometric center of the disc. As compared with the lumbar intervertebral disc, the position of the nucleus pulposus is slightly more anterior in location. This chapter will describe an extradural, right anterior oblique, single-needle, safe and efficient disc access technique. The potential necessity for great vessel displacement is less in this approach compared with the traditional right anterior approach. Correlation with magnetic resonance or CT imaging may be beneficial. The recommended needle gauge is 25 G for intradiscal entry, and the needle tip can be modified as described in Chapter 2 to optimize the needle navigation.

Since the esophagus deviates toward the left, the cervical disc is typically approached from the right. This significantly reduces the likelihood of contacting the esophagus and the devastating potential complication of cervical discitis. Multiplanar imaging will be used to best visualize the needle position.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 29.1)

Patient is supine. Consider having the patient rotate his or her head slightly leftward.
Confirm the level (with the posteroanterior view).
Oblique the fluoroscope to the right.

- The target needle destination is immediately anterior to the junction of the uncinate process (UP) and vertebral body.
- Place a pillow under the patient's neck and right scapula region to achieve 5 to 10 degrees of neck extension and leftward rotation.
- Count down from the C2-C3 level to ensure proper identification of levels.

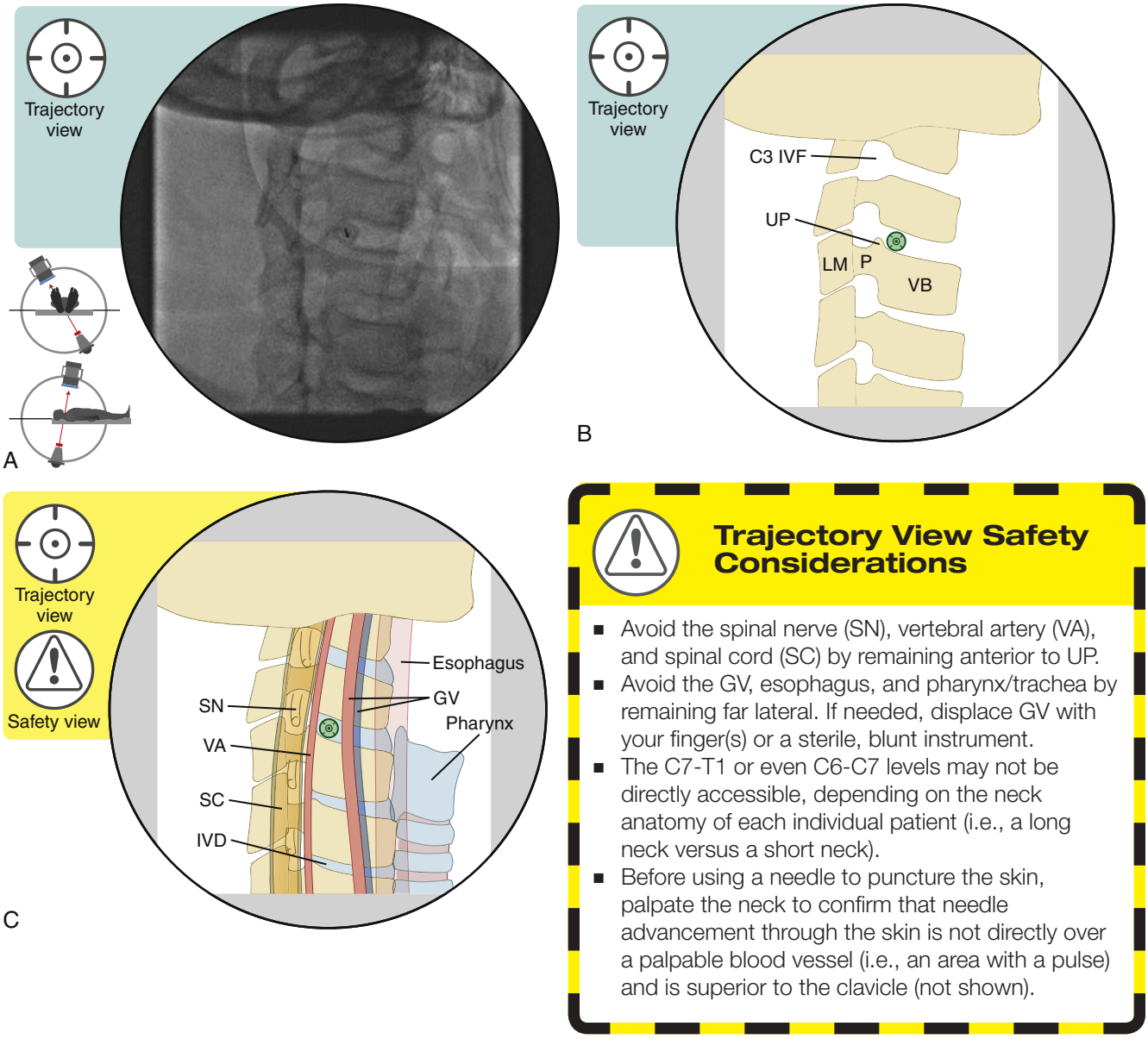
Tilt the fluoroscope's image intensifier usually caudad.

- Line up the vertebral superior end plate and inferior end plate to the appropriate orientation for each individual level.

Place the needle parallel to the fluoroscopic beam.

Notes on Positioning in the Trajectory View

- Setup is adjusted for each individual level.
- Enter from the right side of the neck because the esophagus lies to the left in the lower neck.
- You may need to displace the great vessels (GV) laterally with your index finger.
- Upon needle entry into the disc, the initial needle tip trajectory should be medial.



Trajectory View Safety Considerations

- Avoid the spinal nerve (SN), vertebral artery (VA), and spinal cord (SC) by remaining anterior to UP.
- Avoid the GV, esophagus, and pharynx/trachea by remaining far lateral. If needed, displace GV with your finger(s) or a sterile, blunt instrument.
- The C7-T1 or even C6-C7 levels may not be directly accessible, depending on the neck anatomy of each individual patient (i.e., a long neck versus a short neck).
- Before using a needle to puncture the skin, palpate the neck to confirm that needle advancement through the skin is not directly over a palpable blood vessel (i.e., an area with a pulse) and is superior to the clavicle (not shown).

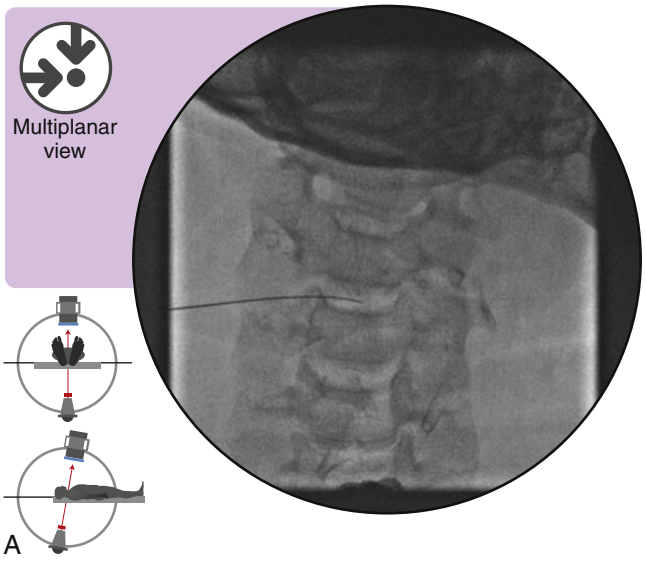
Fig. 29.1. A, Fluoroscopic image of a trajectory view with the needle in position at the C3-C4 level. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

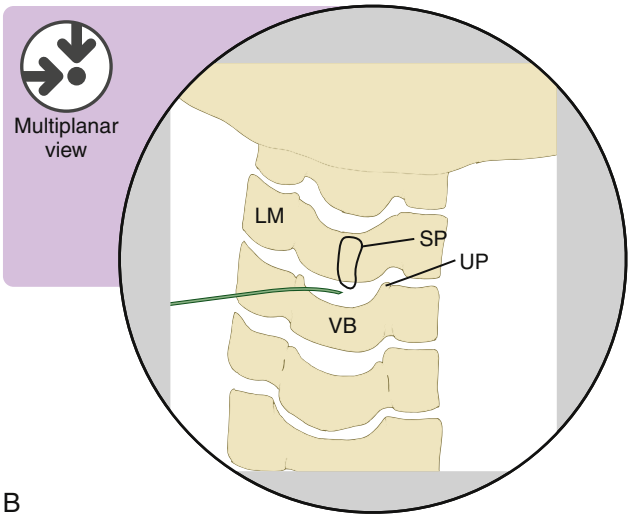
Optimal Needle Position in Multiplanar Imaging

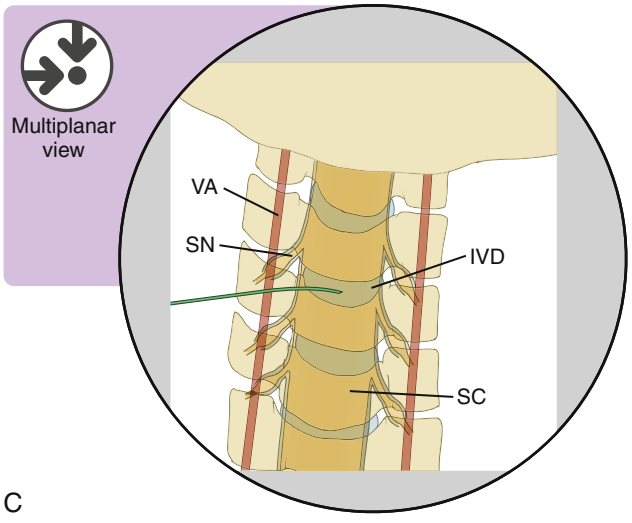
Although cervical discography is performed in a supine patient with an anterior oblique approach, needle localization principles are similar to those for lumbar discography as demonstrated in the lumbar discogram needle localization troubleshooting table (see Table 17A.1).

OPTIMAL NEEDLE POSITIONING IN THE POSTEROANTERIOR VIEW (FIG. 29.2)

The "true" posteroanterior visualization of each individual intervertebral disc is imperative (see Chapter 3).
The geometric center of the disc usually coincides with the position of the spinous process of the superior vertebral body.







- Avoid going beyond the midline position of the intervertebral disc.
- When the needle is in the disc, make minor adjustments to ensure that the needle tip is medially directed.

The main advancement should be done in the lateral view. The contralateral oblique (CLO) view may help somewhat but is not as safe as the lateral view.

Fig. 29.2. A, Fluoroscopic posteroanterior view with the ideal needle position at the C3-C4 level. **B,** Radiopaque structures, posteroanterior view. **C,** Radiolucent structures, posteroanterior view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 29.3)

Notes on Optimal Needle Positioning

- Unlike the lumbar intervertebral disc, the nucleus pulposus is located slightly anterior to the midpoint of the end plate diameter in the lateral view.
- Use multiplanar imaging multiple times so that the needle can be safely and successfully navigated.

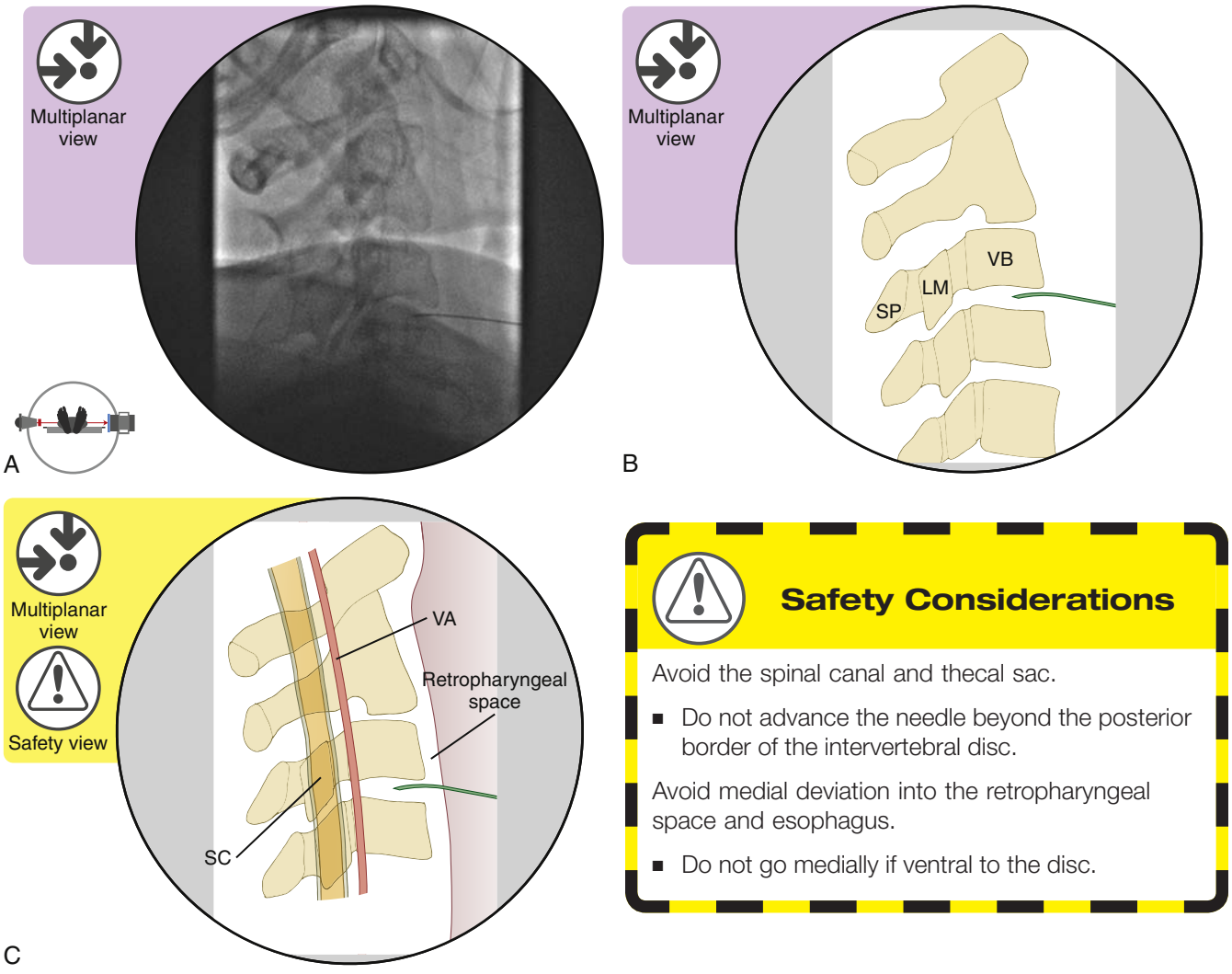


Fig. 29.3. A, Fluoroscopic lateral view with the ideal needle position at the C3-C4 level. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

OPTIMAL NEEDLE POSITIONING IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 29.4)

When performing cervical discography, the lateral visualization of the lower cervical discs can often be a challenge, despite strategies such as the passive depression of the patient's shoulders and the use of a swimmer's view. Another option is to visualize the lower discs using the CLO view. Although this view cannot confirm an ideal intranuclear needle location, it can help to determine the needle tip's location relative to other more superior needle tips. The CLO view is especially helpful to confirm that the needle tip is in a safe intradiscal ventral location away from the dorsally located SC. As always, multiplanar triangulation is encouraged.

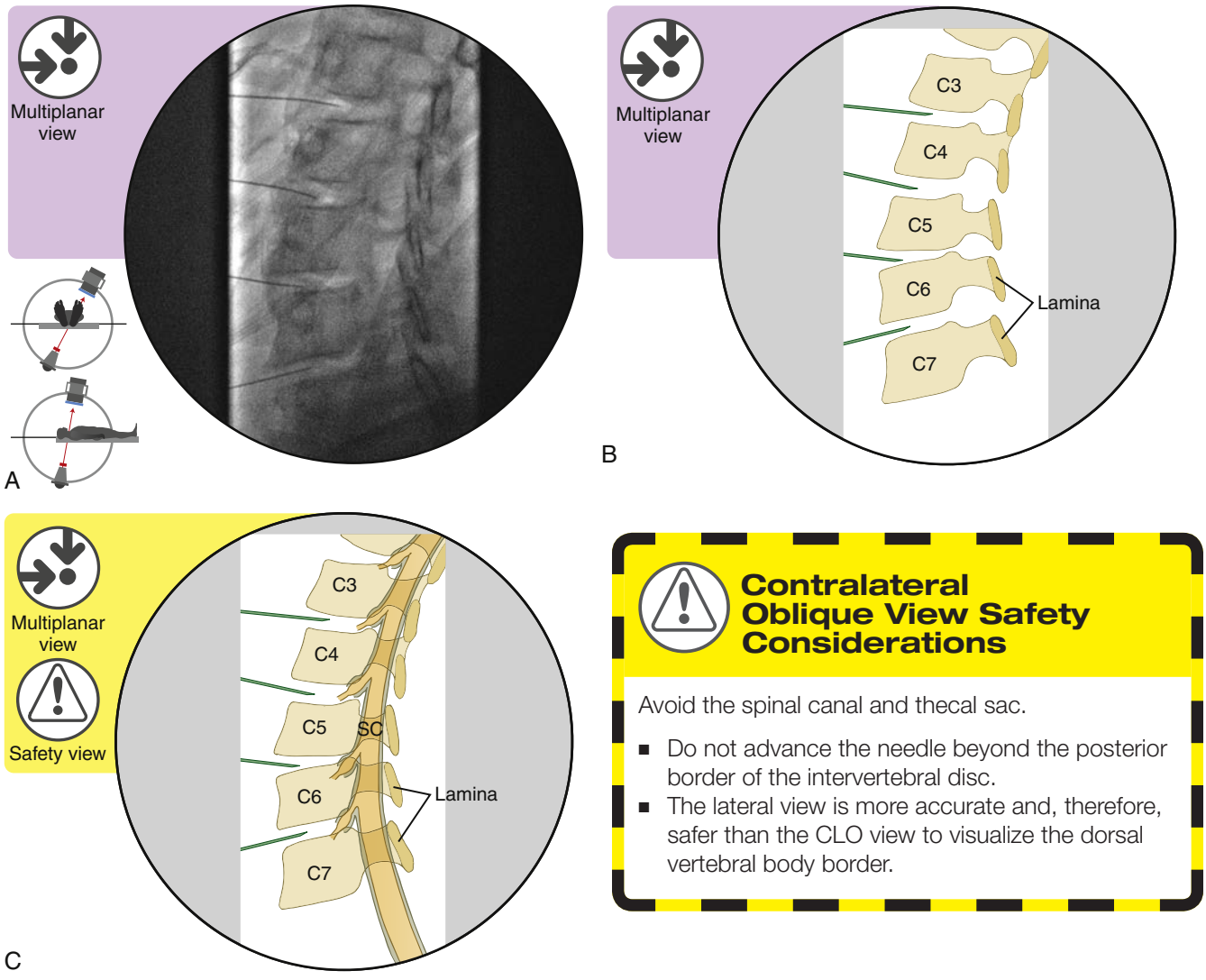


Fig. 29.4. A, Fluoroscopic contralateral oblique view with the ideal needle position and visualization at C6-C7. **B,** Radiopaque structures, fluoroscopic contralateral oblique view. **C,** Radiolucent structures, fluoroscopic contralateral oblique view.

Optimal Images (Figs. 29.5 to 29.7)

Optimal Image

- Ideal flow should begin within the nucleus pulposus, and there should be no immediate disappearance of contrast.
- For normal nondegenerated discs, the flow pattern may be confined to the nucleus pulposus, or it may extend to the uncinate recesses.
- The maximum amount of contrast to be used is less than 0.5 cc.

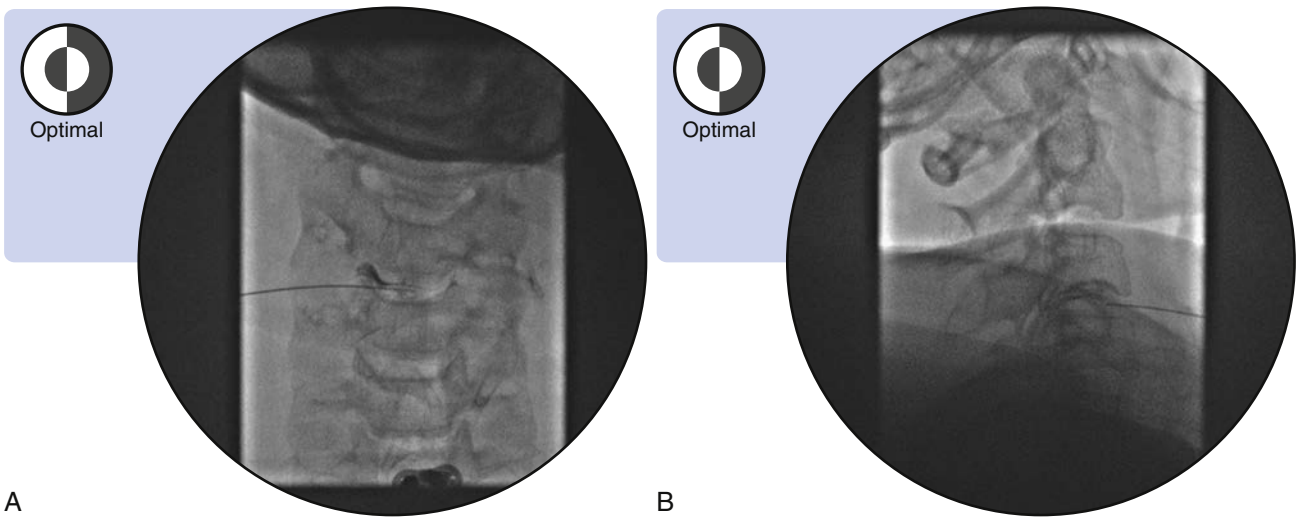


Fig. 29.5. A, Posteroanterior fluoroscopic image of C3-C4 discography with 0.2 cc of contrast medium. **B,** Lateral fluoroscopic image of C3-C4 discography with 0.2 cc of contrast medium.

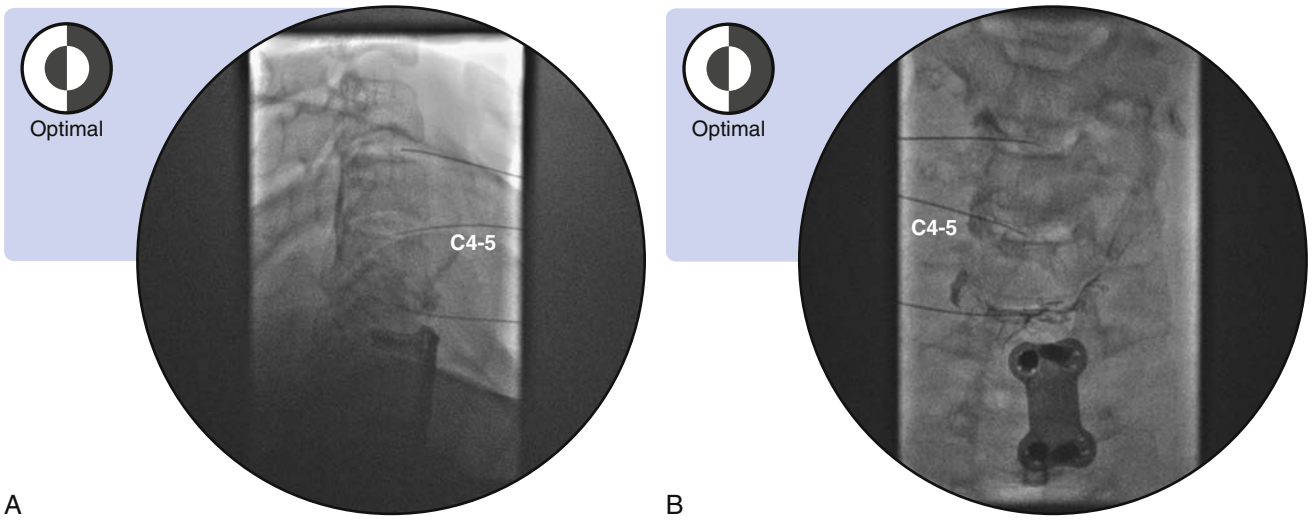


Fig. 29.6. A, Lateral fluoroscopic image of C4-C5 discography with a ruptured nucleogram and the posterior flow of contrast into the epidural space. **B,** Posteroanterior fluoroscopic image of C4-C5 discography with a ruptured nucleogram.

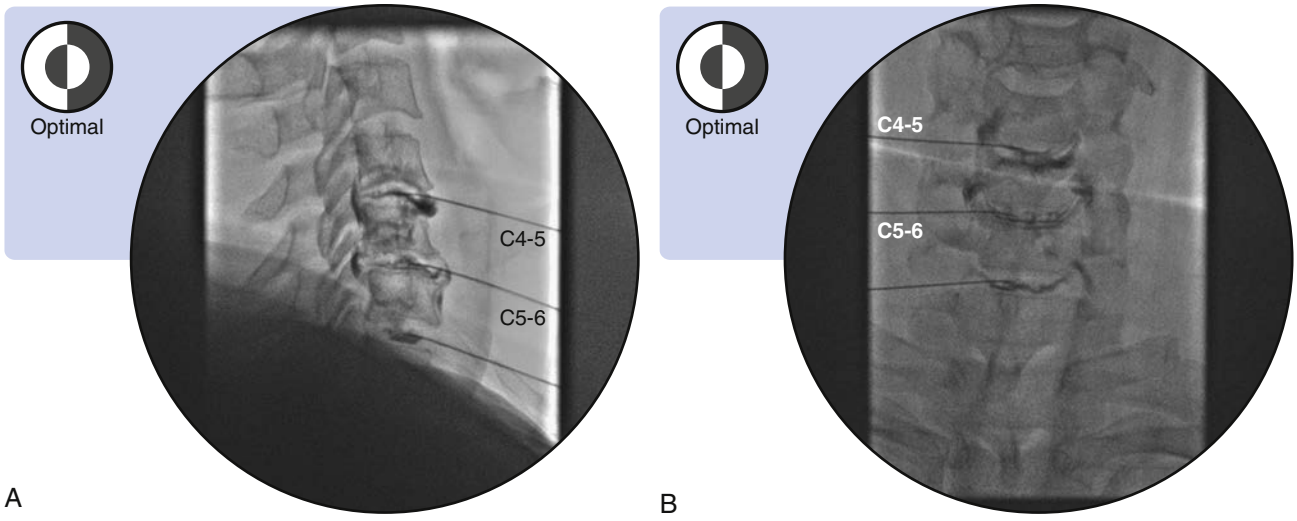


Fig. 29.7. A, Lateral fluoroscopic image of C4-C5 and C5-C6 discography with a fissured nucleogram and the posterior flow of contrast into the epidural space. **B,** Posteroanterior fluoroscopic image of C4-C5 and C5-C6 discography with a fissured nucleogram.

Additional Information

When performing discography, the main data points to consider are as follows:

1. Pain response
   a. Please refer to and follow the lumbar discography recommendations in Chapter 17.
   b. Manometry is not typically used.
      1) Opening pressures may be as high as 200 psi due to the morphologic and structural differences of the cervical intervertebral discs compared with the lumbar intervertebral discs.
      2) Use a 1 cc (or possibly 3 cc) Luer lock syringe for contrast injection. This will allow better incremental contrast injection given the very small possible volume.
2. Nucleogram
   a. Intranuclear
      1) Without the filling of the uncal clefts/recesses (i.e., annular fissures); "cotton ball" appearance
      2) With the filling of the uncal clefts/recesses
   b. Fissured
      1) Circumferential annular disruption
   c. Full-thickness leaking annular tear (i.e., ruptured)

ANTIBIOTICS:

1. Follow the lumbar discography recommendations in Chapter 17.
   a. If postdiscography CT scan is obtained, order 1 to 2 mm parallel slices that may help confirm the location of annular tears. Care should be taken to not confuse the uncinate clefts with an actual tear that will fill the outer annulus in a circumferential manner.

Suboptimal Imaging (Figs. 29.8 and 29.9)

Poor visualization of needle tips at inferior cervical levels.

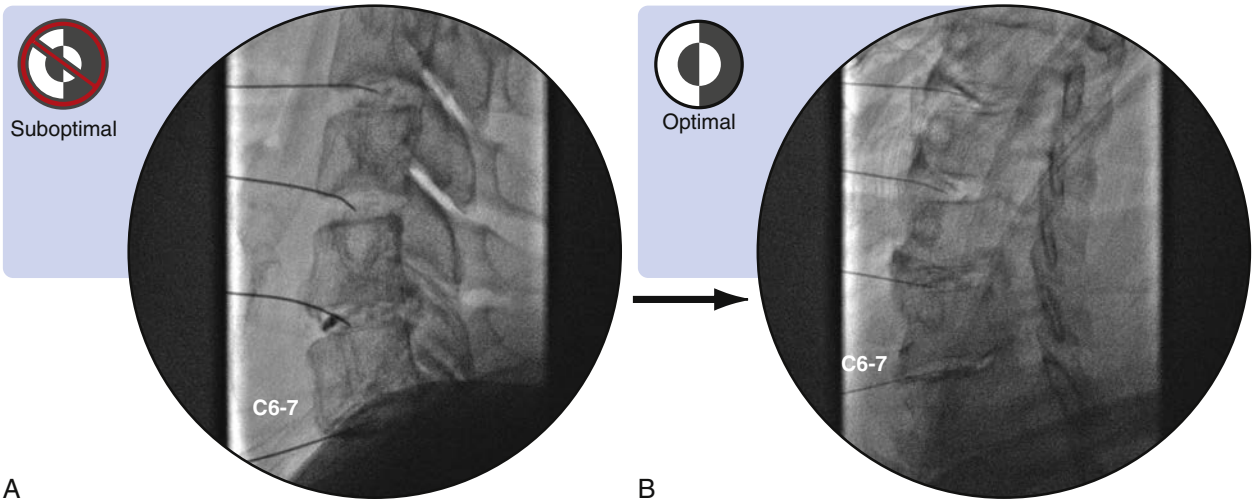


Fig. 29.8. A, A four-level discogram. The more inferior needle tip and contrast pattern at C6-C7 are poorly visualized, despite attempts to correct the patient positioning (e.g., swimmer's view, shoulder relaxation). **B,** After changing to a contralateral oblique view, all four needles, including the one at C6-C7, are well visualized. We still recommend caution, and only use the contralateral oblique to visualize the needle tip positions relative to each other.

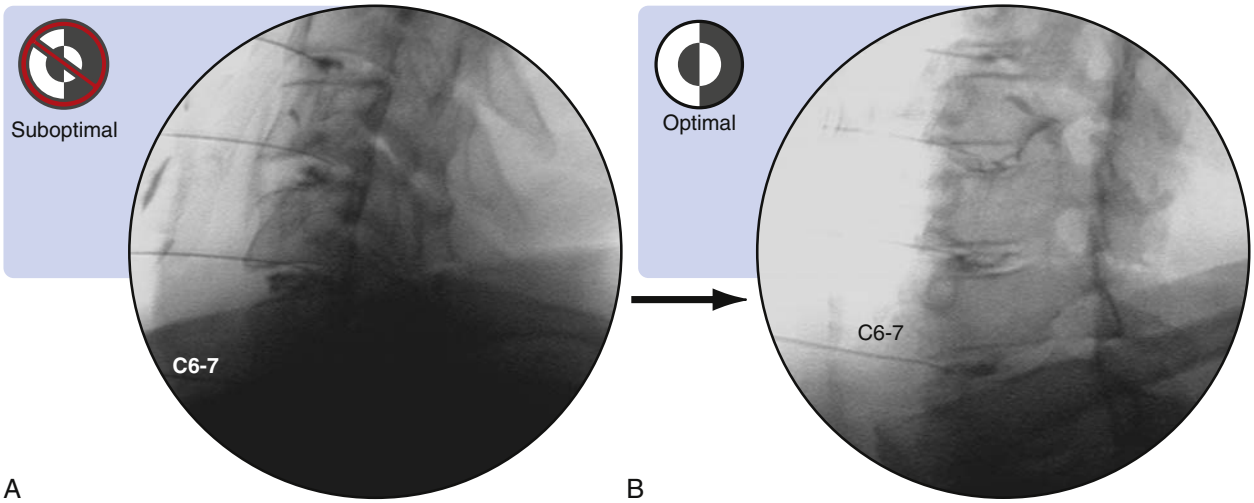


Fig. 29.9. A, Another four-level discogram. The more inferior needle tip and contrast pattern at C6-C7 are poorly visualized, despite attempts to correct the patient positioning (e.g., swimmer's view, shoulder relaxation). **B,** After changing to a contralateral oblique view, all four needles, including the one at C6-C7, are well visualized. We still recommend caution, and only use the contralateral oblique to visualize the needle tip positions relative to each other.

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CHAPTER 30

Cervical Zygapophysial Joint and Medial Branch Nerve Injections and Radiofrequency Neurotomy

The cervical zygapophysial joints (Z-joints) extend bilaterally from C2-C3 to C7-T1. Pain emanating from these joints commonly occurs as a result of a whiplash injury or from a degenerative joint disease. The distribution of the axial cervical pain associated with these joints can extend from the suboccipital region to the mid-scapular region, depending on the Z-joints involved.

Cervical Z-joint injections or medial branch blocks are indicated for the diagnosis and treatment of axial cervical pain. Each Z-joint is innervated by the medial branches above and below the joint, except C2-C3, which is innervated primarily by the third occipital nerve. These joints may be accessed for injection using either a lateral/anterolateral or posterior approach under fluoroscopic or ultasound guidance.

Injections into these joints and medial branches lend well to ultrasound (US) visualization and access because they are relatively superficial. Furthermore, radiolucent structures that cannot be seen on fluoroscopy may be visualized on US, enhancing the safety of these interventions. Three US-guided techniques will be presented using posterior and anterolateral approaches (Chapters 30C, 30E, and 30G). These techniques can be used alone or in conjunction with conventional fluoroscopy in a hybrid technique, thus, eliminating or minimizing exposure to ionizing radiation.

When solely utilizing fluoroscopy, the posterior approach, compared with the lateral approach, allows for access to multiple joint levels on both sides of the spine, without the need to reposition the patient or C-arm. With the posterior approach, the trajectory view is an anteroposterior view with a caudad tilt (i.e., a pillar view) for most levels. The lateral view is used to assess (ventral) depth. A contralateral oblique/foraminal oblique view (see Chapter 3) is an additional multiplanar safety view that can be used as a relative depth view.

The lateral approach is well suited for cervical medial branch blockade, especially for the upper segments. Some argue that the lateral approach is technically less demanding than the posterior approach: it can be performed using a smaller-gauge needle (e.g., 25 or 26 G), and less soft tissue is traversed. The trajectory view is the lateral view. The foraminal oblique view (see Chapter 3) will assist in visualizing the lower segments and is an excellent safety view to visualize the foramina with its associated neural and vascular (vertebral artery) radiolucent structures, which may be obscured by the shoulders on a lateral view. Also, a pillar anteroposterior or posteroanterior multiplanar view will help guide access into the Z-joint space, especially with degenerated joints. It can also serve as a safety view to prevent overpenetration into the spinal cord.

Contrast flow into the Z-joint followed by spread into the retroligamentous "space of Okada" is a common phenomenon (see Fig. 30B.5B).

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Special attention should be paid to Chapter 30H, which illustrates the variability of the cervical medial branch nerves' anatomic courses and demonstrates recommended radiofrequency transducer positions and lesion zones.

Cervical radiofrequency (RF) denervation (i.e., neurotomy) is typically performed after significant pain relief is documented with diagnostic medial branch blocks. The approach to cervical radiofrequency ablation or neurotomy is posterior. The RF electrode tip is placed so that the neurotomy occurs parallel to the nerve. Because there is anatomic variation with regard to the course of the medial branch nerve, many practitioners perform two to four denervations at each level. In Chapter 30G, we describe a pragmatic trajectory. Some (Spine Intervention Society[6]) recommend a technique that includes both sagittal and oblique passes at each level by varying the obliquity and tilt except for C7, which only requires a sagittal pass.

When cervical RF neurotomy is performed, the needle is placed using a trajectory view and advanced using multiplanar imaging, with an emphasis on safely using the lateral and contralateral (foraminal) oblique views (see Chapter 3) to confirm the depth. Before denervation, 0.5 to 1 cc of anesthetic is typically placed. The time and duration of the denervation vary with different practitioners (e.g., two to four 90-second cycles at 80°C to 85°C).

Chapter 30G focuses mostly on radiofrequency denervation; however, the same posterior approach is also suited for medial branch blocks.

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CHAPTER 30A

Cervical Zygapophysial Joint Intraarticular Injection, Posterior Approach: Fluoroscopic Guidance

William A. Rollé, Jr., Bradly S. Goodman, Isaac Cohen, and Michael B. Furman

In this chapter, the posterior approach for injecting the zygapophysial joints (Z-joints) is described. Compared with the lateral approach, the posterior approach allows for access to multiple joint levels on both sides of the spine, thereby negating the need to reposition the patient or C-arm when performing bilateral injections. This approach is often required for injecting the more inferior Z-joints, where a lateral approach may involve the risk of contacting the lung apex or the inferior neurovascular structures. With this approach, the trajectory view is an anteroposterior view with a caudad tilt (i.e., a pillar view), which also serves as the anteroposterior view with multiplanar imaging. Because the lateral view is used to assess depth, one need not step off of the inferior or superior articulation of the joint before penetrating the joint capsule, as is often recommended. A contralateral oblique (CLO) view is an additional multiplanar view and can be used as a relative depth view. Typically a 22- or 25-G needle is used to inject a maximum volume of 1 ml of a steroid and anesthetic mixture into each cervical Z-joint.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

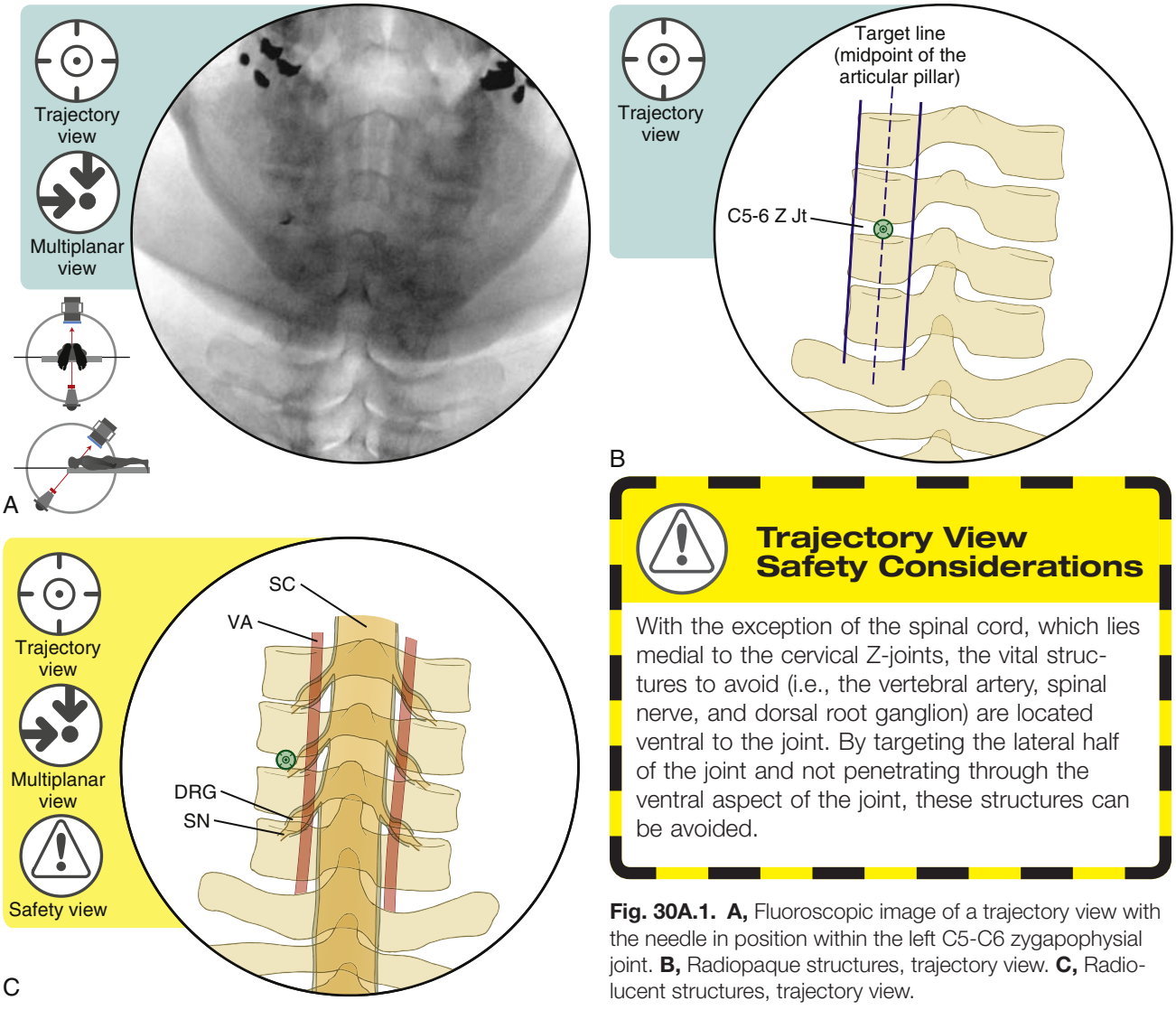
Trajectory View (Fig. 30A.1)

- **Confirm the level** (with the anteroposterior view).
- **Tilt the fluoroscope's image intensifier caudally** to orient the beam parallel to the plane of the Z-joint.
- An optimal tilt is indicated by a hyperlucent, horizontal joint space with crisp bony margins.
- **Place the needle** parallel to the fluoroscopic beam into the cervical Z-joint.

The Trajectory View (AP) Is Also a Multiplanar View

Notes on Positioning in the Trajectory View

Please note that the setup is performed for each level separately by changing tilt. The obliquity may also need to be adjusted depending on the head position and/or other anatomical considerations.



Trajectory View Safety Considerations

With the exception of the spinal cord, which lies medial to the cervical Z-joints, the vital structures to avoid (i.e., the vertebral artery, spinal nerve, and dorsal root ganglion) are located ventral to the joint. By targeting the lateral half of the joint and not penetrating through the ventral aspect of the joint, these structures can be avoided.

Fig. 30A.1. A, Fluoroscopic image of a trajectory view with the needle in position within the left C5-C6 zygapophysial joint. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

The multiplanar views are AP, lateral, and CLO.

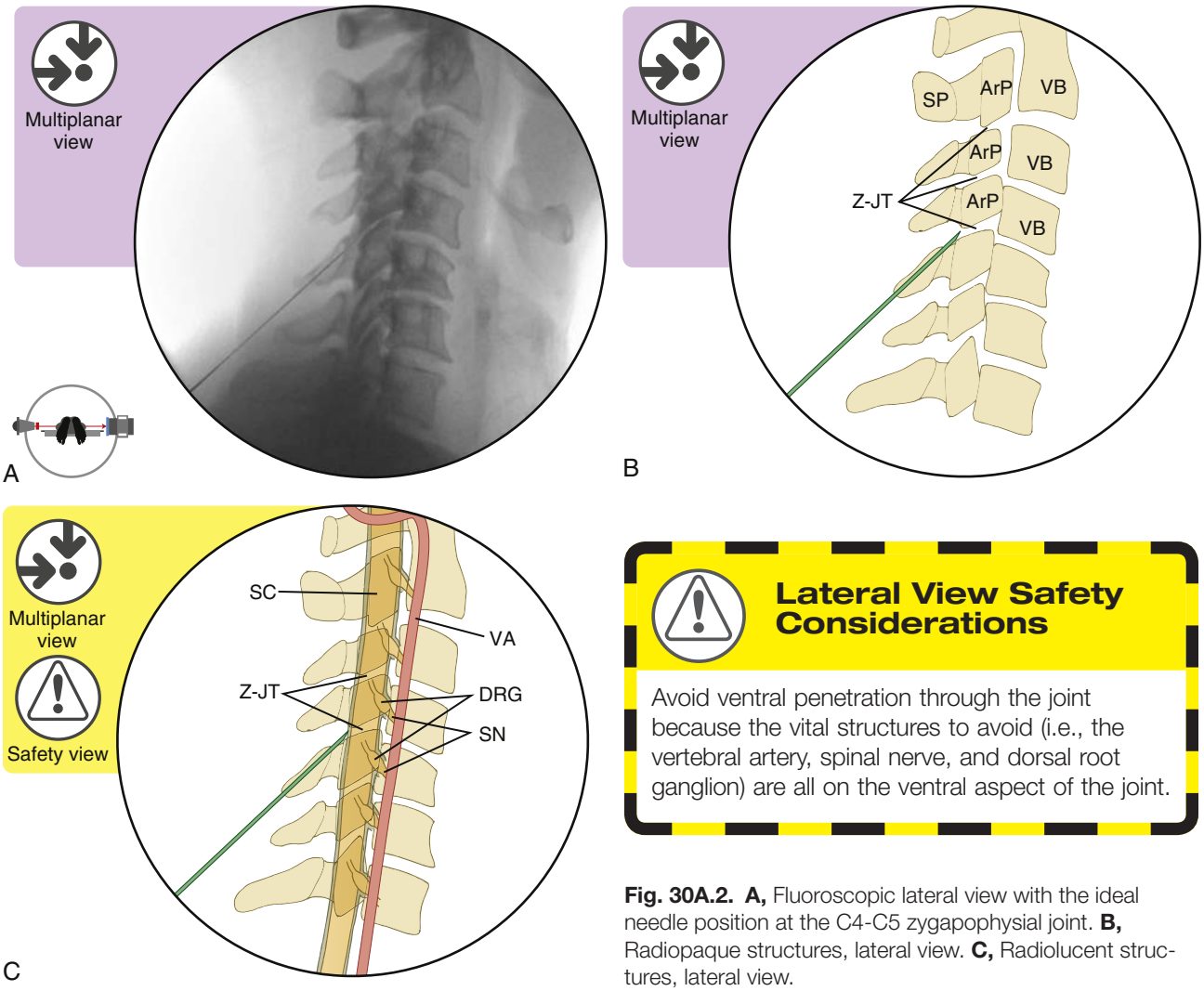
Notes on Optimal Needle Positioning

The needle tip should remain within the joint silhouette in multiple planes.

The Trajectory View (AP) Is Also a Multiplanar View

See Figs. 30A.1A-C on the previous page for AP imaging.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 30A.2)



Lateral View Safety Considerations

Avoid ventral penetration through the joint because the vital structures to avoid (i.e., the vertebral artery, spinal nerve, and dorsal root ganglion) are all on the ventral aspect of the joint.

Fig. 30A.2. A, Fluoroscopic lateral view with the ideal needle position at the C4-C5 zygapophysial joint. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

OPTIMAL NEEDLE POSITIONING IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 30A.3)

The CLO view is obtained by obliquing approximately 30 degrees contralaterally from the setup view. The ipsilateral foramen (i.e., the foramen closest to the needle tip) is visualized. The CLO view is particularly useful when the joint cannot be visualized in the lateral view, thereby providing a relative depth view. With the exception of the spinal cord, which lies medial to the cervical Z-joints, the vital structures to avoid (i.e., the vertebral artery, spinal nerve, and dorsal root ganglion) are located ventral to the joint. There is no reference point with regard to the degree of obliquity. See Chapter 3, Fig. 3.18, for more discussion).

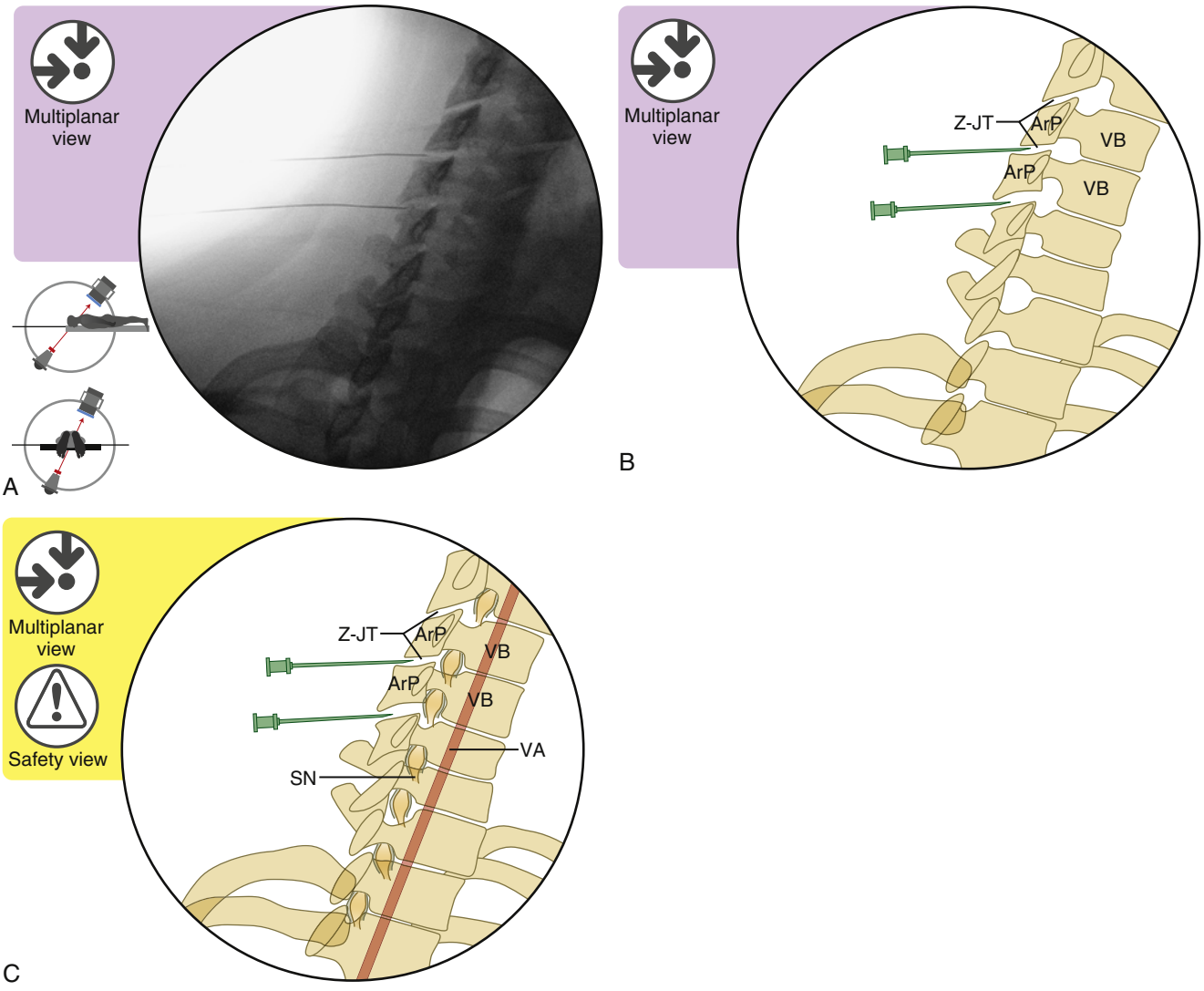


Fig. 30A.3. A, Fluoroscopic contralateral oblique (CLO) view (in another patient) with needles in the ideal position of the left C4-C5 and C5-C6 zygapophysial joints. **B,** Radiopaque structures, CLO view. **C,** Radiolucent structures, CLO view.

Optimal Images (Figs. 30A.4 to 30A.6)

Ideal contrast flow should appear horizontal and even elliptical in the anteroposterior view. In the lateral view, contrast flow should outline the orientation of the joint line, and it may be seen in the most anterior aspect of the joint. When performing cervical Z-joint injections, contrast flow into the space of Okada is a common phenomenon. This is discussed and demonstrated in Chapter 30B.

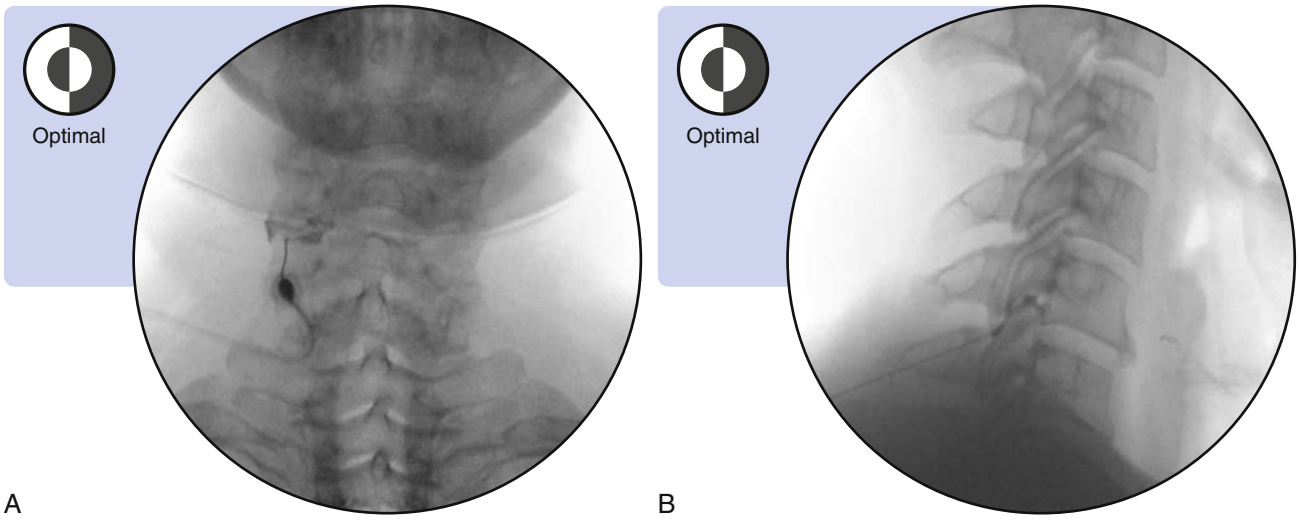


Fig. 30A.4. A, Anteroposterior fluoroscopic image of a left C5-C6 zygapophysial joint injection with 0.25 cc of contrast. **B,** Lateral fluoroscopic image of a left C5-C6 zygapophysial joint injection with 0.25 cc of contrast.

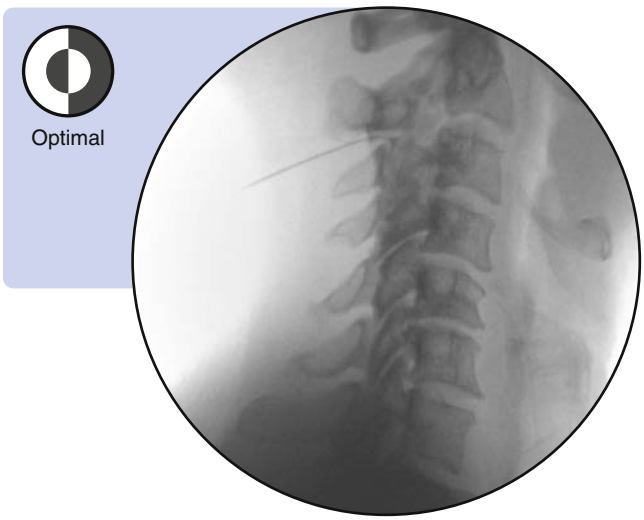


Fig. 30A.5. Contrast is seen to flow within the confines of the C2-C3 zygapophysial joint space. Fluoroscopic image of optimal flow.

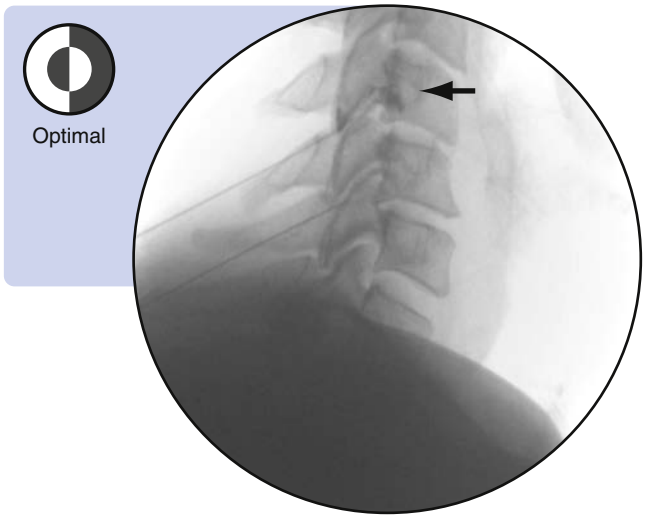


Fig. 30A.6. Fluoroscopic image of optimal flow in the C5-6 jZ-joint (*arrow*).

Suboptimal Images (Figs. 30A.7 and 30A.8)

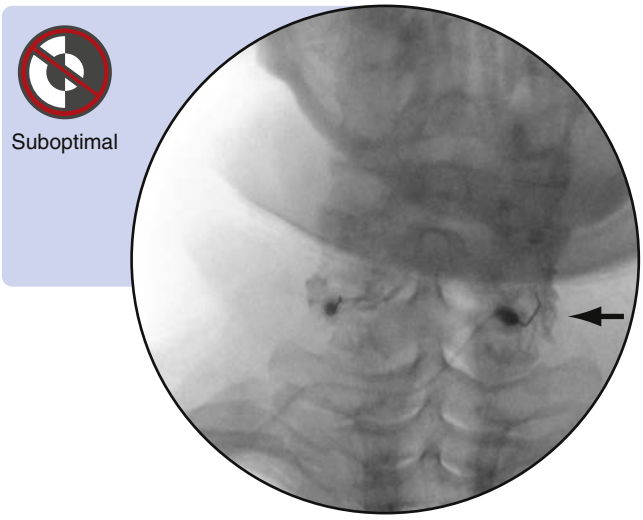


Fig. 30A.7. The left C6-C7 zygapophysial joint (Z-joint) injection represents an optimal contrast image. The right C6-C7 Z-joint injection (*arrow*) represents a suboptimal contrast image because the contrast is seen flowing laterally outside the boundary of the joint.

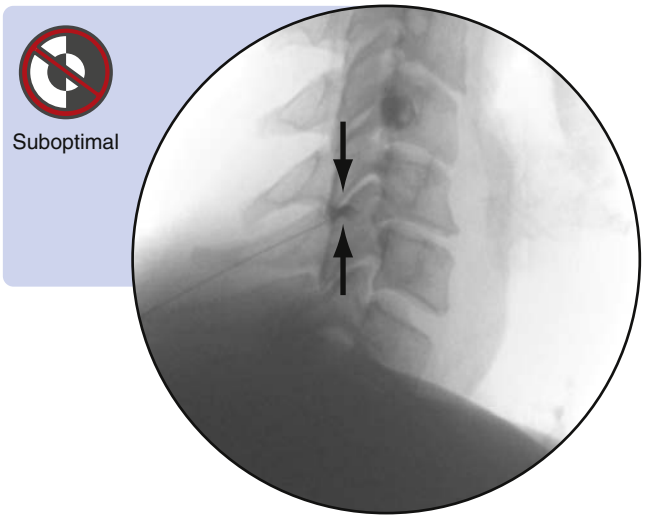


Fig. 30A.8. The C6-C7 zygapophysial joint injection represents a suboptimal image because contrast is seen flowing outside of the confines of the joint (*arrows*), and there is no intraarticular flow into the anterior aspect of the joint.

References

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CHAPTER 30B

Cervical Zygapophysial Joint Intraarticular Injection, Lateral Approach: Fluoroscopic Guidance

Tejas N. Parikh, Bradly S. Goodman, and Michael B. Furman

In this chapter, the lateral approach to performing a cervical zygapophysial joint (Z-joint) intraarticular injection is described. Some may argue that the lateral approach is technically less demanding than the posterior approach: it can be performed with the use of a smaller-gauge needle (e.g., 25 or 26 G), and less soft tissue is traversed, thereby making it more comfortable for the patient. Regardless of the approach used, the total volume of anesthetic and steroid injected should be less than 1 ml to prevent the rupture of the joint capsule and leakage into adjacent structures.

The more cephalad cervical joints are featured in this chapter. This approach can be more challenging in the more caudad segments as the shoulders can obscure target visualization in the lateral projection and anteroposterior (AP) views. An ipsilateral/foraminal oblique view (see Chapter 3, Figs. 3-19) can be used when there is difficulty visualizing the joint or to confirm needle placement in the correct cervical Z-joint. When performing cervical Z-joint injections, contrast flow into the space of Okada is a common phenomenon. The space of Okada is an extradural space dorsal to the ligamentum flavum. Contrast injection will flow initially into the Z-joint and then out the inferior recess of the joint and track medially into this retroligamentous space (see Fig. 30B.5).

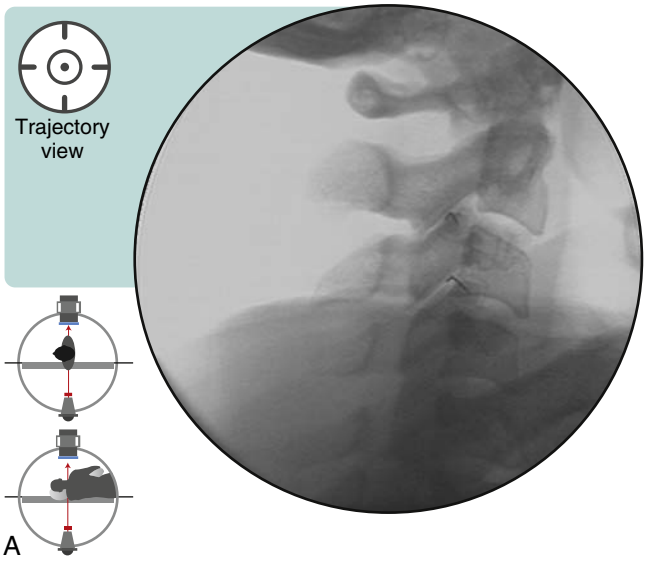
Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

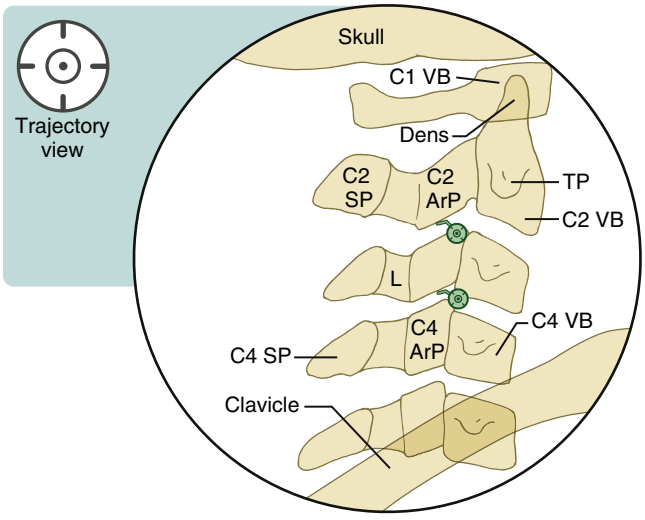
Trajectory View (Fig. 30B.1)

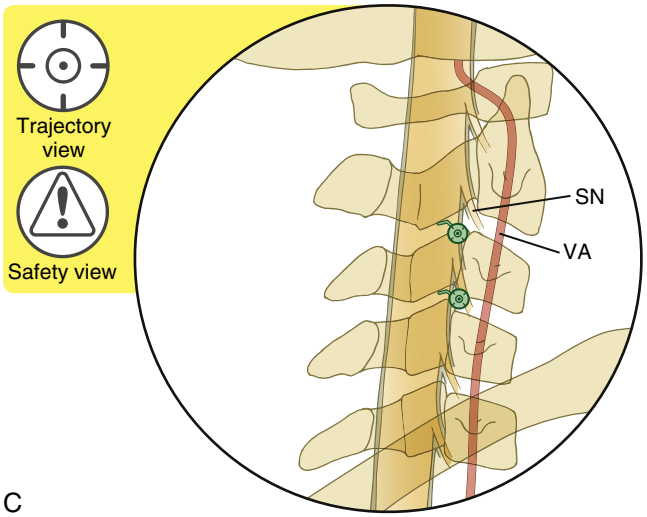
The Trajectory View (Lateral) Is Also a Multiplanar View

Place the patient in a lateral decubitus position with the symptomatic side up.

- Confirm the level using a lateral view (relative to the patient—zero degrees relative to the table if the patient lies perpendicular to it).
- Identify the target by counting down from C2.
  If needed, **tilt the fluoroscope slightly** in a cranial or caudad direction to superimpose the ipsilateral and contralateral facet joints and articular pillars.
- Because the patient is in a lateral decubitus position, the tilt will be used as discussed in Chapter 3.
  If needed, also **oblique the fluoroscope slightly** to superimpose the ipsilateral and contralateral facet joints and articular pillars.
- Because the patient is in a lateral decubitus position, the oblique will be used as discussed in Chapter 3.
  The lateral image is the trajectory view, and the needle is placed parallel to the fluoroscopic beam.
- To differentiate superimposed ipsilateral from contralateral cervical Z-joints, use one of the techniques described in Chapter 3.







Trajectory View Safety Considerations

- Avoid the spinal nerve and vertebral artery by not placing the needle too far ventral.
- Depending on patient anatomy (i.e., "short neck"), access to the lower cervical segments may be compromised by the lung apices.

Fig. 30B.1. A, Fluoroscopic image of a trajectory view with the needle in position in the right C2-C3 and C3-C4 zygapophysial joints. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

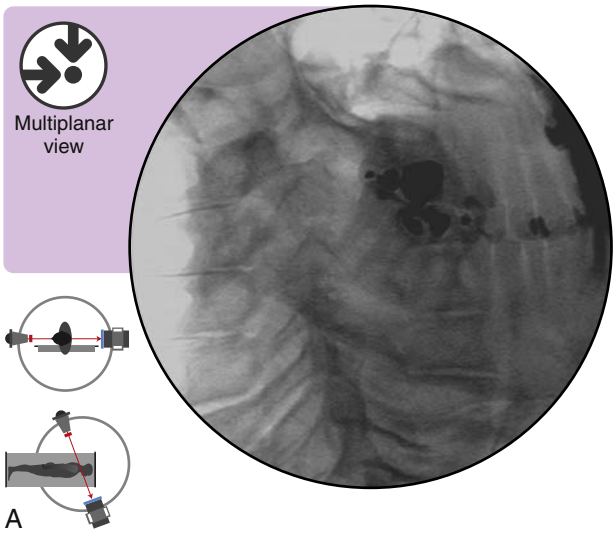
The multiplanar views used are the lateral, AP, and ipsilateral oblique (to view the foramina ventral to the Z-joints.). The patient is side-lying.

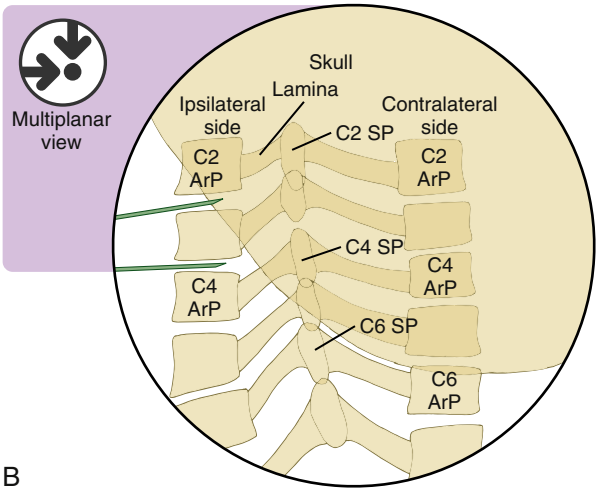
The Trajectory View (Lateral) Is Also a Multiplanar View

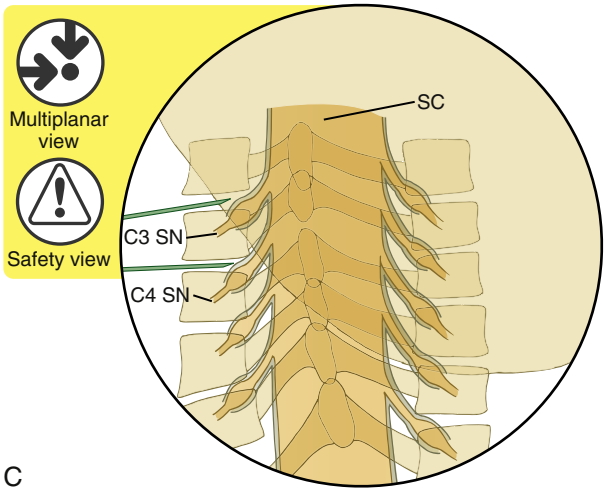
See Figures 30B.1 for lateral views.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR (PILLAR) VIEW (FIG. 30B.2)

- After the needle tip position is confirmed in the trajectory view (or, in this case, the lateral view), obtain an AP image by positioning the C-arm 90 degrees oblique.
- After positioning the C-arm 90 degrees oblique (AP in a side-lying patient), the fluoroscope is adjusted with wig-wagging (see Chapter 3, Table 3.2). Wig-wagging in a side-lying patient is similar to tilting in a prone patient to obtain the pillar view. With this adjustment, the C-arm is wig-wagged (cranio-caudad relative to the patient) to optimize articular pillar and facet joint visualization (the articular pillar view). For the right-sided procedure (pictured in Fig. 30B.2), the image intensifier is rotated cephalad, and the image source is rotated caudad in relation to the patient. (See the wig-wag fluoro icon in Figure 30B.2A.)
- This AP projection is also known as the *pillar view.*







Anteroposterior View Safety Considerations

- Avoid the spinal cord by not placing the needle too far medial.

Fig. 30B.2. A, Fluoroscopic anteroposterior view with the ideal needle position in the right C2-C3 and C3-C4 zygapophysial joints. The gray rectangle in the bottom fluoroscopic icon represents the table on which the side-lying patient rests. To obtain an articular pillar view in a side-lying patient, the fluoroscopic "wig-wag" is used (see Chapter 3). **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

OPTIMAL NEEDLE POSITIONING IN THE IPSILATERAL FORAMINAL OBLIQUE VIEW (TO VISUALIZE THE FORAMINA VENTRAL TO THE Z-JOINTS) (FIG. 30B.3)

- The ipsilateral oblique view can be obtained to confirm correct needle placement or to guide the needle into the joint (see Chapter 3, Fig. 3.19).
- This ipsilateral oblique separates the ipsilateral and contralateral articular pillars/lateral masses so they are not superimposed on each other.
- The joints of interest are located posterior to the ipsilateral foramen.

Notes on Obtaining the "Ipsilateral Foraminal Oblique" View

- To obtain an articular pillar view in a side-lying patient, the fluoroscopic "wig-wag" is used (see Chapter 3). See Chapter 3, Figs. 3.16 to 3.19 on how to obtain an ipsilateral foraminal oblique view.

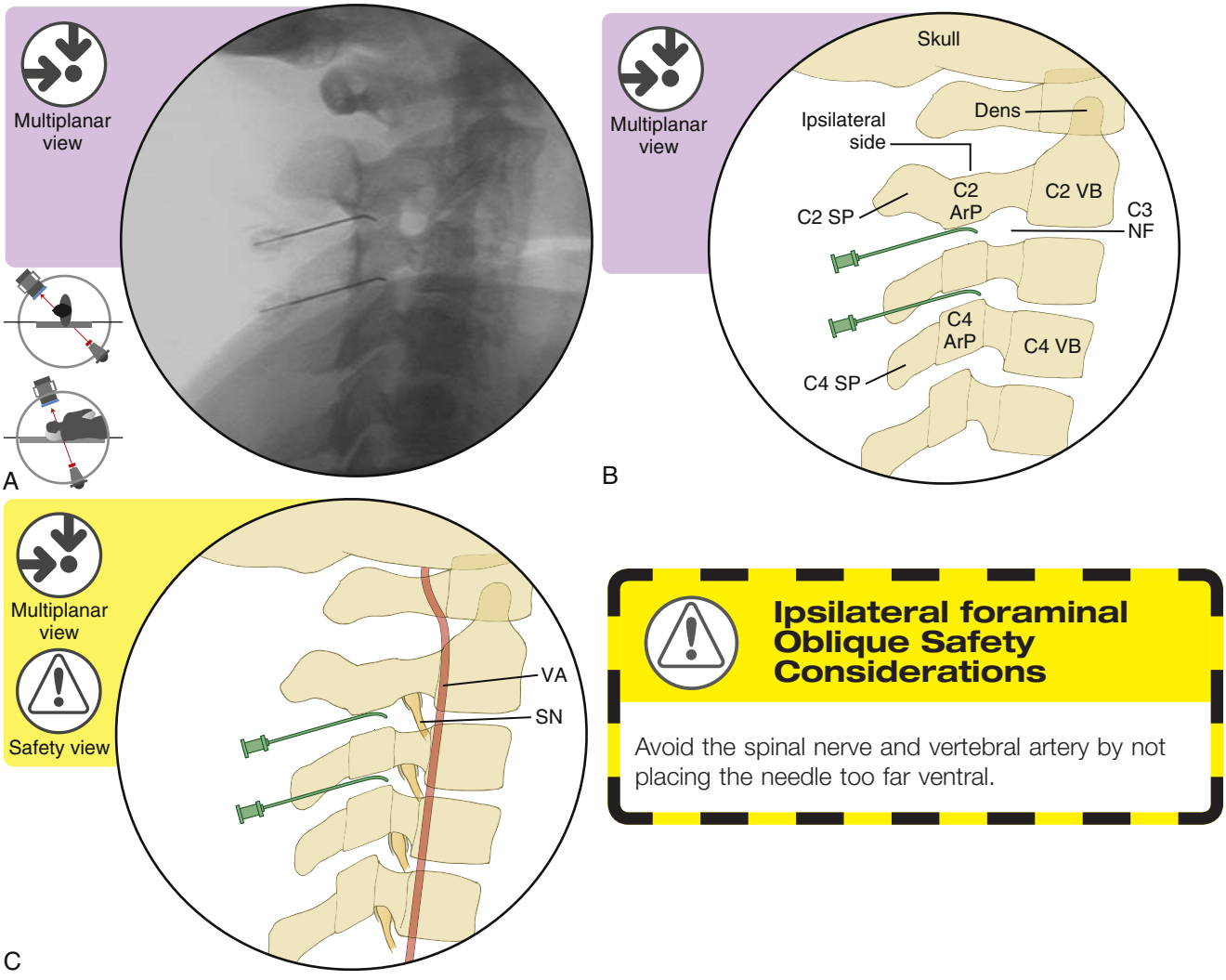


Fig. 30B.3. A, Fluoroscopic ipsilateral foraminal oblique view with the ideal needle position in the right C2-C3 and C3-C4 zygapophysial joints. **B,** Radiopaque structures, ipsilateral foraminal oblique view. **C,** Radiolucent structures, ipsilateral foraminal oblique view.

Optimal Image (Fig. 30B.4)

- Optimal flow should be intraarticular and may extend to the inferior and/or superior joint recesses.
- Less than 0.5 ml of contrast should be injected into this small joint to allow for the therapeutic injectate.

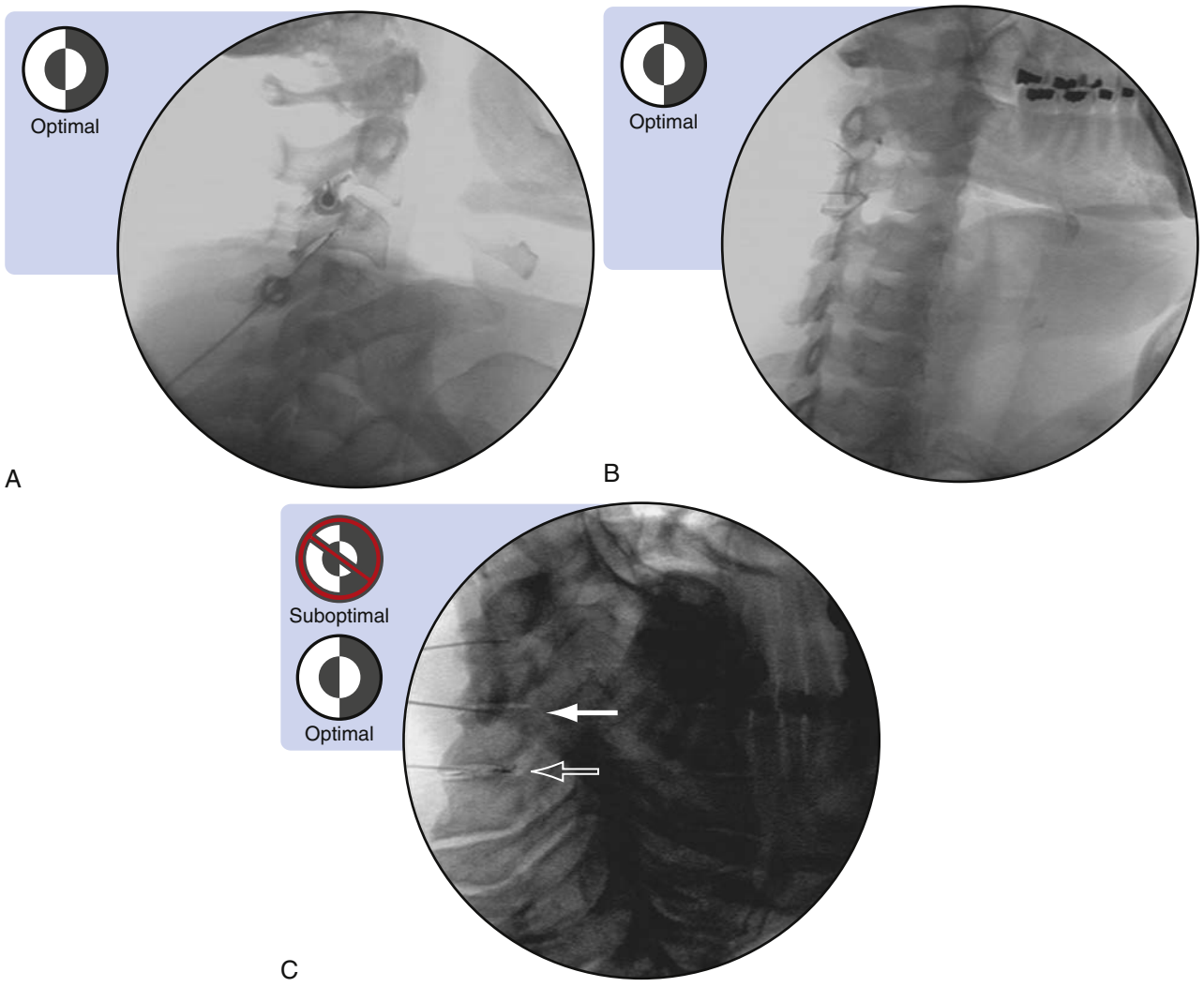
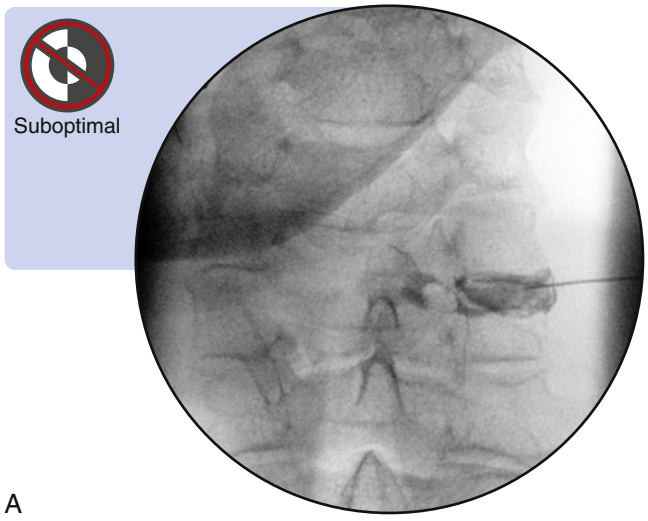


Fig. 30B.4. A, Lateral fluoroscopic image of the right C2-C3 and C3-C4 zygapophysial joints (Z-joints) with optimal flow. Note the linear contrast flow pattern between the anterosuperior and posteroinferior margins of the joints. **B,** Ipsilateral foraminal oblique fluoroscopic image of the right C2-C3 and C3-C4 Z-joints with optimal flow. Notice the flow pattern outlining the joint margins. **C,** Anteroposterior fluoroscopic image of a right C4-C5 Z-joint injection with optimal flow (*open arrow*). Note the linear contrast flow pattern between the medial and lateral joint margins. Suboptimal flow is noted in the right C3-C4 Z-joint (*closed arrow*). Note how the contrast obscures the joint margins.

Suboptimal Image (Fig. 30B.5)

- Contrast can oftentimes flow into the extradural space dorsal to the ligamentum flavum known as the "space of Okada" (Fig. 30B.5B).
- Flow into the space of Okada is a normal variant and not pathologic. Contrast injected into the space of Okada will have an oblique pattern that extends toward midline and may also flow into the contralateral joint.
- Comments about contrast flow into the space of Okada.

While an AP image demonstrates medial extravasation, a lateral view will show contrast within the Z-joint and posterior to the spinolaminar line between the spinous processes. This flow pattern should not be confused with epidural extravasation that may occur from a pathologic defect in the medial capsule of the Z-joint. Extravasation into the epidural space or the retroligamentous space of Okada can be considered a suboptimal injection if the procedure is being done primarily for diagnostic purposes. These occurrences could compromise specificity with diagnostic injection. Extravasation might be acceptable for therapeutic injection.



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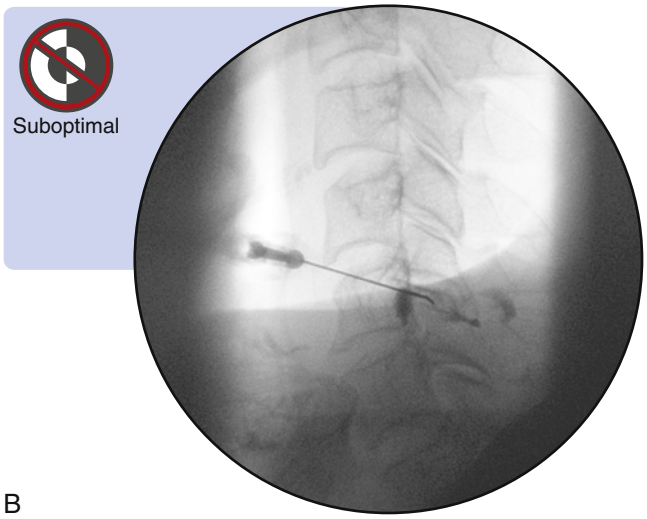

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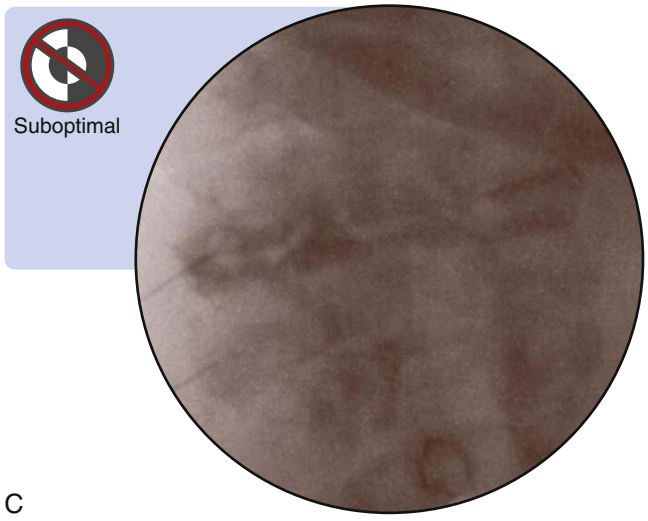

C

Fig. 30B.5. A, Anteroposterior (AP)/pillar view image of a left C5-C6 zygapophysial joint (Z-joint) injection. Contrast fills the joint and extravasates into the retroligamentous "space of Okada." This medial spread is not epidural as it is flowing behind the ligamentum flavum. **B,** Lateral image of the same left C5-C6 Z-joint injection. Contrast is seen extending out the inferior recess posterior to the joint. This is a common and unavoidable occurrence, which is acceptable for therapeutic purposes, but suboptimal with respect to diagnostic specificity. **C,** AP/pillar view in another patient of a left C4-C5 and C5-C6 Z-joint injection. At C4-C5, there is spread of injectate from the left C4-C5 Z-joint to the retroligamentous "space of Okada" and into the contralateral right C4-C5 Z-joint. There is injectate wash-out at C5-C6. See Fig. 25.7A and 25.7B, which illustrate contrast flow into the space of Okada and bilateral C6-C7 facet joints during a cervical interlaminar epidural steroid injection.

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CHAPTER 30C

Cervical Zygapophysial Joint Nerve (Medial Branch) Injection—Anterolateral Approach: Ultrasound Guidance

Louis Torres, Simon J. Shapiro, Paul S. Lin, and Michael B. Furman

Cervical facet joint nerves (medial branches, MB) can be safely, effectively, and efficiently accessed with ultrasound (US) guidance by an experienced interventionalist. The structures involved are relatively superficial and, thus, lend themselves well to US visualization. Furthermore, radiolucent structures (vertebral artery, spinal nerve, etc.) that cannot be seen on fluoroscopy may be visualized on US, enhancing the safety of this intervention.

In this chapter, we present an anterolateral approach for cervical MB nerve injections, oftentimes referred to as medial branch blocks, with an out-of-plane technique with in-plane confirmation. This technique can be used alone or in conjunction with conventional fluoroscopy in a hybrid technique, thus, eliminating or minimizing exposure to ionizing radiation.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Out-of-Plane Technique (Fig. 30C.1)

- The patient is side-lying, facing the interventionalist (see Fig. 30C.1A).
- The US unit is positioned on the opposite side to the interventionalist and in line with the transducer (as described in Chapter 4).
- Utilize a linear transducer, as the structures of interest are relatively superficial.
- Identify the vertebral artery at C2 (see Chapter 4).
- Use the techniques described in Chapter 4 to identify and mark the target level.
- Setup is the key. Once properly identified, there is typically a very short distance to traverse to the target.
- Start with the transducer in long axis to the cervical spine (coronal). Identify the zygapophysial joints (Z joint, peaks) and articular pillars (troughs).
- Stay over the hyperechoic articular pillar, which is slightly deeper and flatter in contrast to the adjacent Z-joint capsules, which are relatively rounded, elevated, and superficial in comparison. The MB nerve is located at the trough on the articular pillar between the Z-joints.
- Using an out-of-plane technique, insert the needle with a steep anterior-to-posterior trajectory and advance the needle to the target (see Chapter 30H for a diagram of the location of the cervical MB).
- Avoid too shallow of a needle entry angle to prevent placement too posteriorly.
- The shaft of the needle appears as a single dot.
  - Needle rotation or "jiggle" can help visualize the needle in the out-of-plane view.

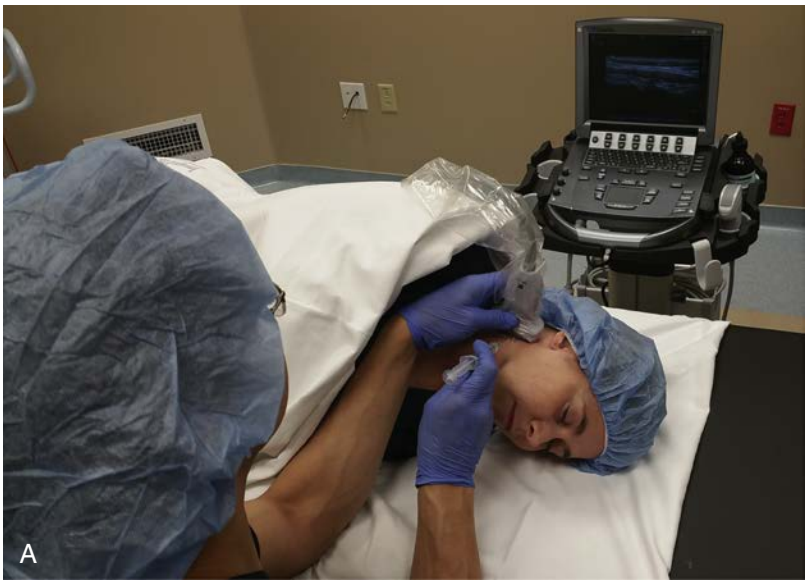

Fig 30C.1. A, Recommended room, interventionalist, transducer and US setup with simulated patient in side-lying position.

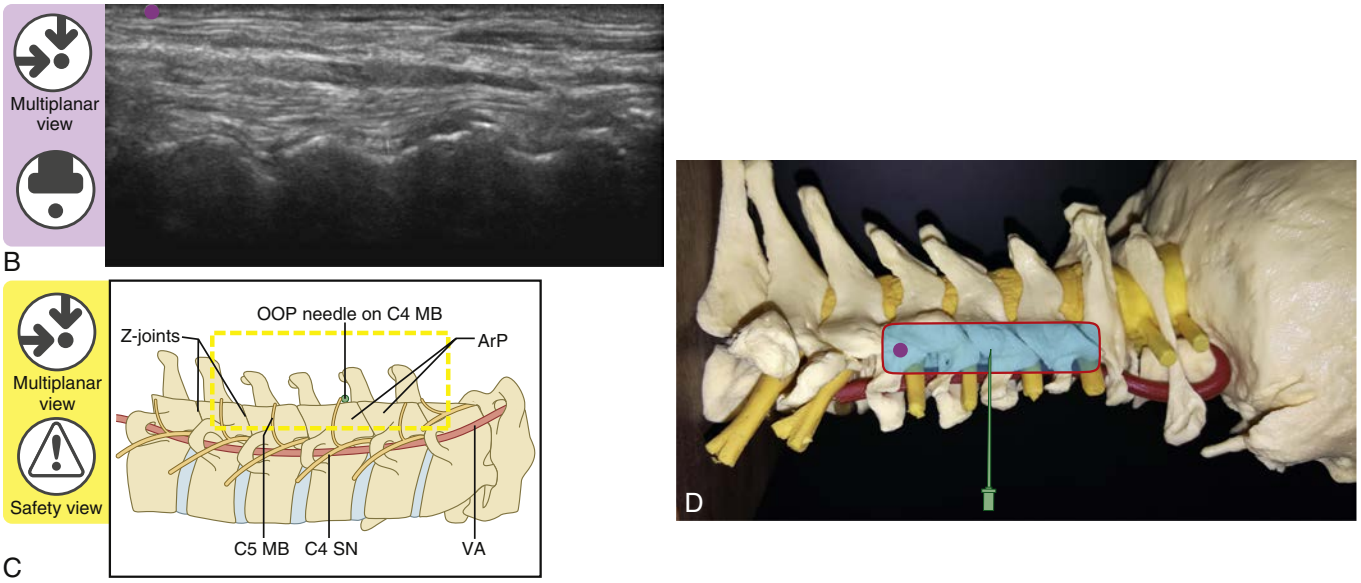

Fig. 30C.1. B, Ultrasound (US) out-of-plane needle placement image at the targeted MB on the articular pillar "valley." **C**, Drawing of relevant structures corresponding to Fig. 30C.1A. Yellow dashed line represents US image borders seen in Fig. 30C.1B. Note that the medial branches lay in the "valleys" of the articular pillars. The Z joints form "peaks." **C,** Proper US transducer placement. **D,** Room and interventionalist injection setup.

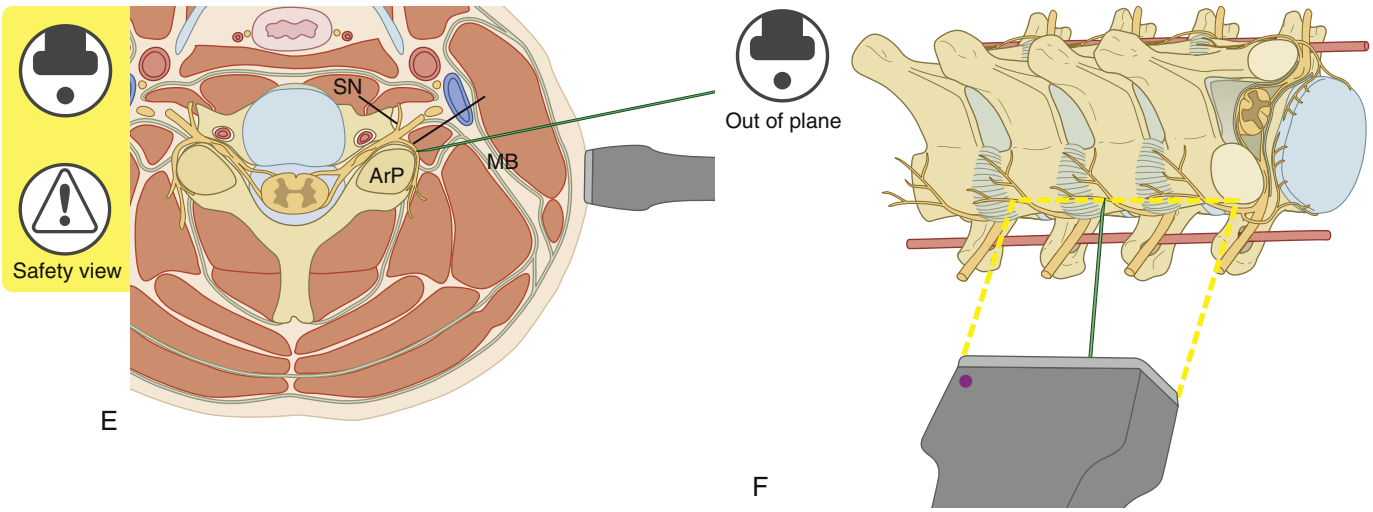

Fig. 30C.1. E, Two-dimensional representation of transducer position. Because this is an out-of-plane technique, we are viewing along the transducer. **F,** Three-dimensional representation of transducer position.

Out-of-Plane Technique Safety Considerations

- Avoid starting with too steep of an angle of entry; this can place the needle too anterior and in proximity to the vertebral artery and spinal nerves.

In-Plane Confirmation (Fig. 30C.2)

- Rotate the transducer 90 degrees to obtain an in-plane confirmation view.
- Visualize the length of the needle with the tip on the periosteum at the target location on the articular pillar.
- If necessary, re-position the needle tip so that it is at the desired location on the articular pillar (see Chapter 30H, cervical MB location diagram).

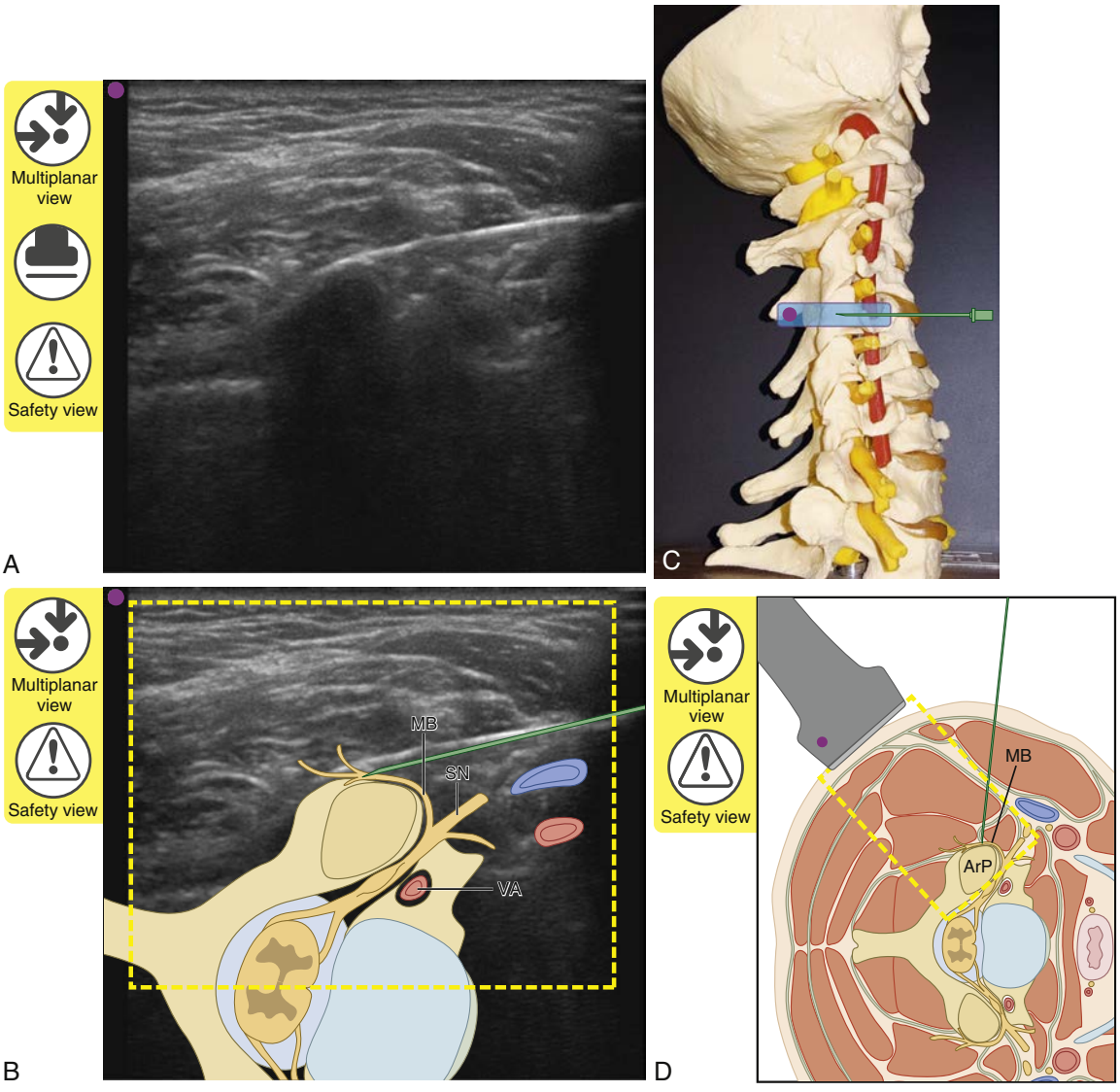

Fig. 30C.2. A, Ultrasound (US) in-plane confirmation needle placement view at the targeted MB on the articular pillar. **B**, Drawing/overlay of relevant structures corresponding to Fig. 30C.2A. Yellow dashed line represents US image borders seen in Fig. 30C.2A. **C,** Proper US transducer placement demonstrating 90-degree rotation from the out-of-plane view. **D,** Stylized drawing of relevant structures corresponding to Fig. 30C.2A. Yellow dashed line represents US image borders seen in Fig. 30C.2A.

In-Plane Technique Safety Considerations

- Avoid the anteriorly located vertebral artery and spinal nerves.

Optimal Needle Placement and Image (Fig. 30C.3)

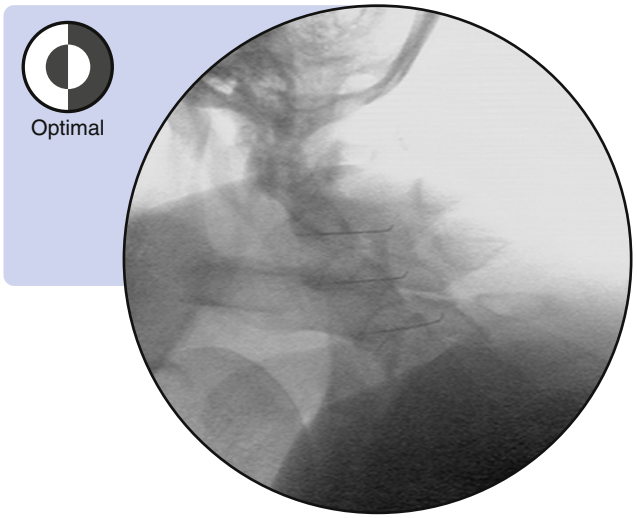

Fig. 30C.3. Fluoroscopic lateral view correlation after ultrasound-guided (USG) cervical medial branch block needle placement at the third occipital nerve (TON), C3, and C4 (anterior approach). The TON placement is positioned too cephalad and needs to be repositioned. Also**,** note that there is a more ventral approach when using this USG technique when compared with the conventional lateral fluoroscopic technique.

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CHAPTER 30D

Cervical Zygapophysial Joint Nerve (Medial Branch) Injection—Lateral Approach: Fluoroscopic Guidance

Tejas N. Parikh, Jeffrey R. Conly, and Michael B. Furman

This chapter describes the lateral approach to fluoroscopically guided cervical medial branch injection. The cervical Z-joints are a well-documented source of acute and chronic neck pain. Symptomatic cervical Z-joints typically produce axial pain. In addition, the upper Z-joints may demonstrate sclerotomal referral patterns that radiate superiorly and anteriorly to involve the head, whereas the lower joints demonstrate patterns that radiate inferiorly and laterally to involve the shoulder and the upper thoracic region.[1] The patient's history, physical examination, and imaging studies will be suggestive of but not specific for Z-joint pain. The standard for the diagnosis of zygapophysial joint (Z-joint) pain is diagnostic medial branch anesthetic injections.[2] Cervical medial branch blocks may also have a therapeutic benefit.[3] Each Z-joint is innervated by two medial branch nerves. Typically, a lateral projection is best suited for cervical medial branch blockade, especially for the upper segments. The foraminal oblique view (Chapter 3) will assist in visualizing the lower segments, particularly at C7, which may be obscured on a lateral view.

Note that this is one of the few procedures in which the trajectory view is the lateral view (i.e., one of the multiplanar views).

Special attention should be paid to Fig. 30H.1, which illustrates the variability of the cervical medial branch nerves' anatomic courses.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 30D.1)

Tilt the fluoroscope cephalad or caudad.
- Line up the vertebral superior end plate and the inferior end plate to the appropriate orientation.
- Superimpose the articular pillars.

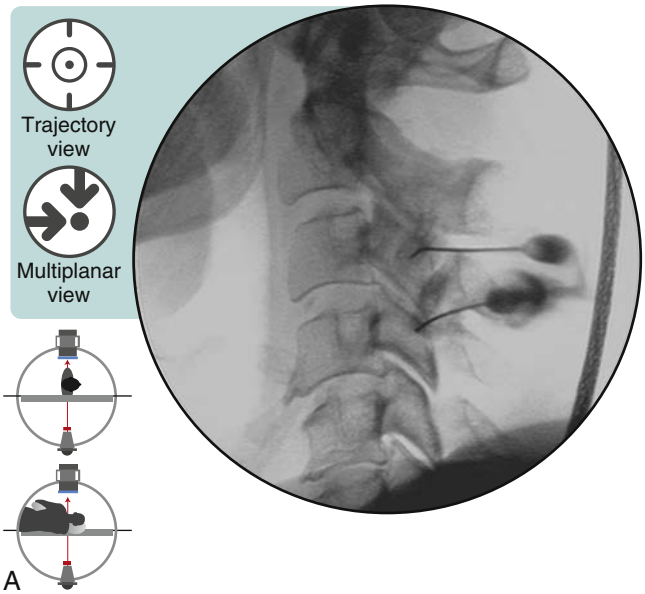
Oblique the fluoroscope minimally (i.e., keep it near neutral).
- Note that a slight degree of obliquity may be required to superimpose the articular pillars to obtain a trapezoid view.

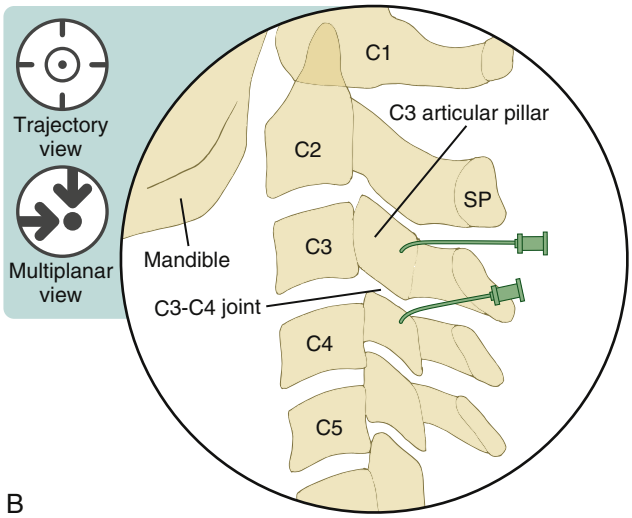
Confirm the level by counting inferiorly from C2.
- The target needle destination depends on the targeted medial branch.
- The needle is advanced by remaining parallel to the fluoroscopic beam until the periosteum is encountered. See Chapter 30H for the exact location of medial branches.
- To differentiate superficial ipsilateral vs. deeper contralateral cervical medial branches, use one of the techniques described in Chapter 3.

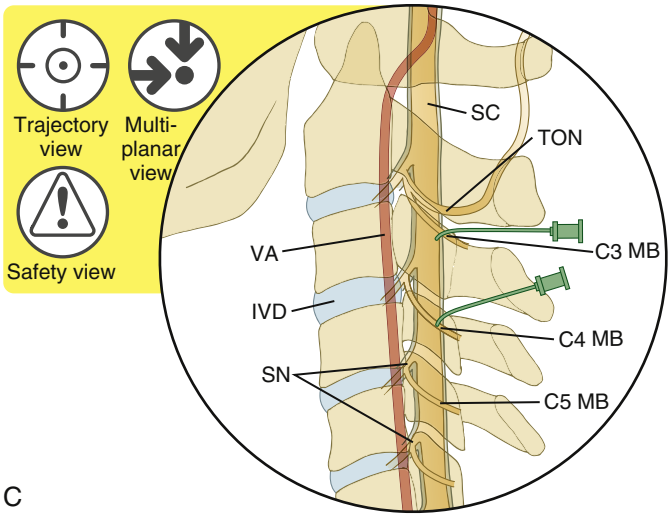
The Trajectory View (Lateral) Is Also a Multiplanar View

Notes on Positioning in the Trajectory View

- The needle is placed parallel to the fluoroscopic beam.
- Please note that setup is performed separately for each level by changing the tilt and obliquity as necessary.
- See Chapter 30H for a diagram of the exact locations of medial branches.







Trajectory View Safety Considerations

- Avoid the spinal nerve and vertebral artery anteriorly.
- Avoid inadvertent needle placement too superiorly or inferiorly into the intraarticular joint and potential penetration into the dural sac or spinal cord.

Fig. 30D.1. A, Lateral fluoroscopic image for C3 and C4 medial branch block. Note that the lateral view is the same as the trajectory view. Ideally, the needles should be visualized down their shaft as a "hubogram" (not shown). **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

The multiplanar images include lateral, anteroposterior (AP), and foraminal oblique.

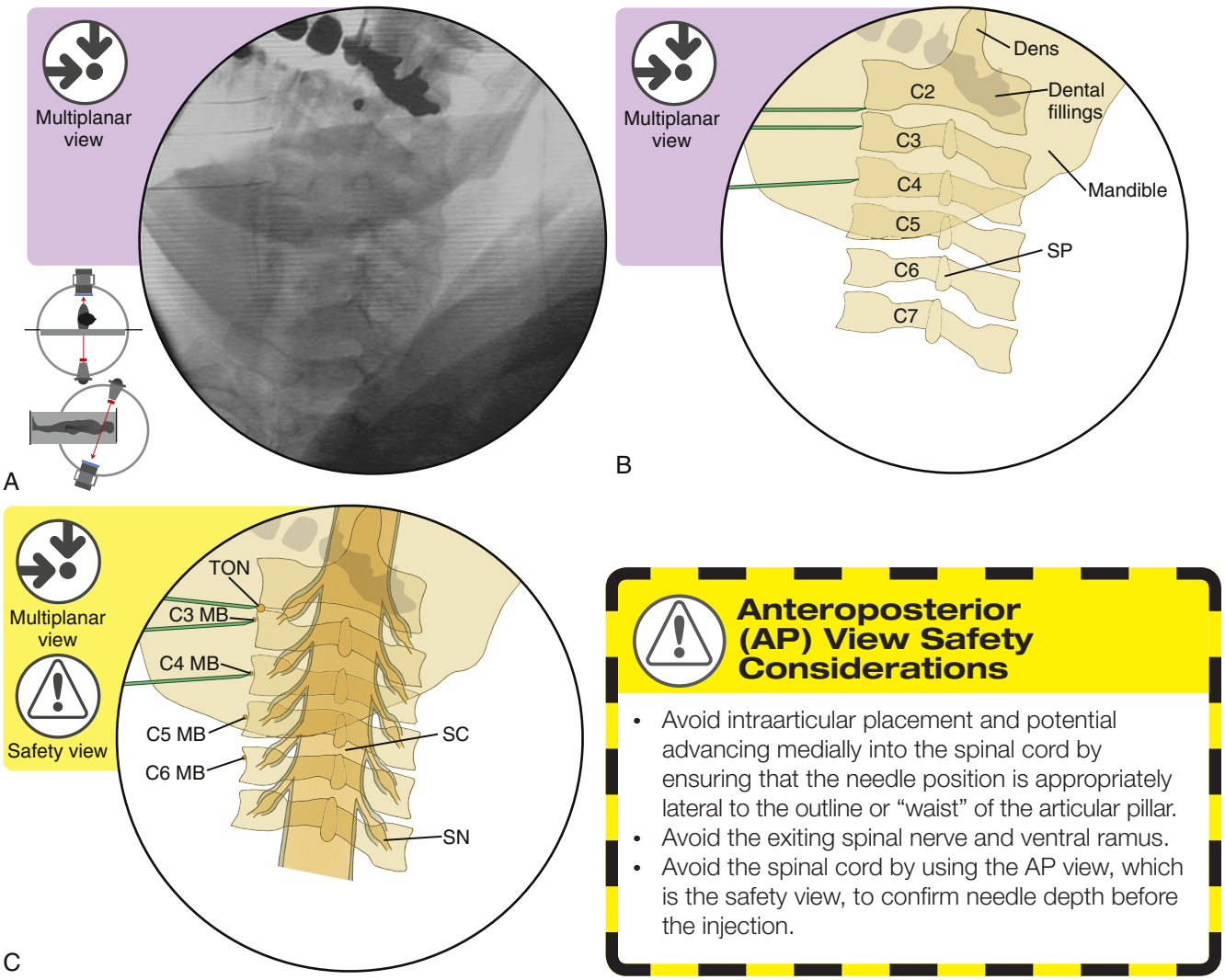
OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW

- For cervical medial branch blocks from the lateral approach, the lateral view is the same as the trajectory view.
- The safety considerations for the lateral view are the same as those for the trajectory view.

The Trajectory View (Lateral) Is Also a Multiplanar View

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR (PILLAR) VIEW (FIG. 30D.2)

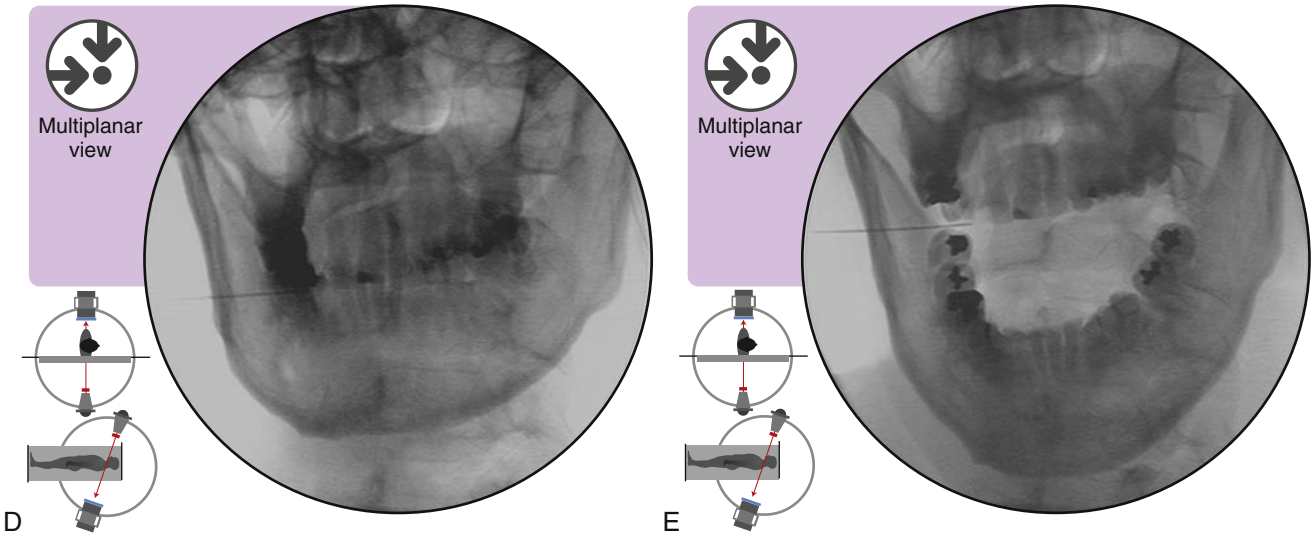
- After the needle tip position is confirmed in trajectory view (or, in this case, the lateral view), obtain an AP image by positioning the C-arm 90 degrees oblique.
- After positioning the C-arm 90 degrees oblique (AP in a side-lying patient), the fluoroscope is adjusted with wig-wagging (see Chapter 3, Table 3.2). Wiig-wagging in a side-lying patient is similar to tilting in a prone patient to obtain the pillar view. With this adjustment, the C-arm is wig-wagged (cranio-caudad relative to the patient) to optimize articular pillar and facet joint visualization (the articular pillar view). For the left-sided procedure pictured in Fig. 30D.2, the image intensifier is rotated caudad, and the image source is rotated cephalad in relation to the patient. (See the wig-wag fluoro icon in Fig. 30D.2A.)
- This AP projection is also known as the *pillar view.*



Anteroposterior (AP) View Safety Considerations

- Avoid intraarticular placement and potential advancing medially into the spinal cord by ensuring that the needle position is appropriately lateral to the outline or "waist" of the articular pillar.
- Avoid the exiting spinal nerve and ventral ramus.
- Avoid the spinal cord by using the AP view, which is the safety view, to confirm needle depth before the injection.

Fig. 30D.2. A, Fluoroscopic anteroposterior (AP) articular pillar view with the needles positioned to target the cervical medial branches of the upper third occipital nerve (TON), C3, and C4. The gray rectangle in the bottom fluoroscopic icon represents the table on which the side-lying patient rests. **B,** Radiopaque structures, AP view. Note the midline positioning of the spinous processes (*SP*), angle of the mandible, and dens. The needle tip lies within the bony lateral groove near the location of the target medial branches.



Notes on Obtaining Anteroposterior/Pillar View

- Obtain AP view as described in Chapter 3.
- Wig-wag the image intensifier to align the fluoroscopic beam parallel to cervical Z-joints and properly visualize the "waist" of the articular pillars. To obtain an articular pillar view in a side-lying patient, the fluoroscopic "wig-wag" is used, which is similar to using a "tilt" in a prone or supine patient (see Chapter 3, Table 3.1).
- An open mouth view may optimize visualization when dentition overlies the structures.

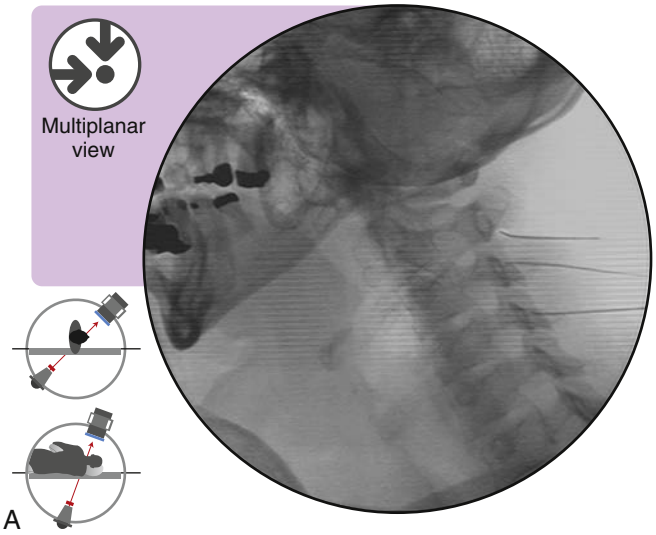
Fig. 30D.2, cont'd. C, Radiolucent structures, AP view. **D,** Fluoroscopic AP view with the needle along C2-C3 (TON). Closed mouth view. **E,** Open mouth view. Please see Figure 30H to better visualize the course of the cervical medial branches.

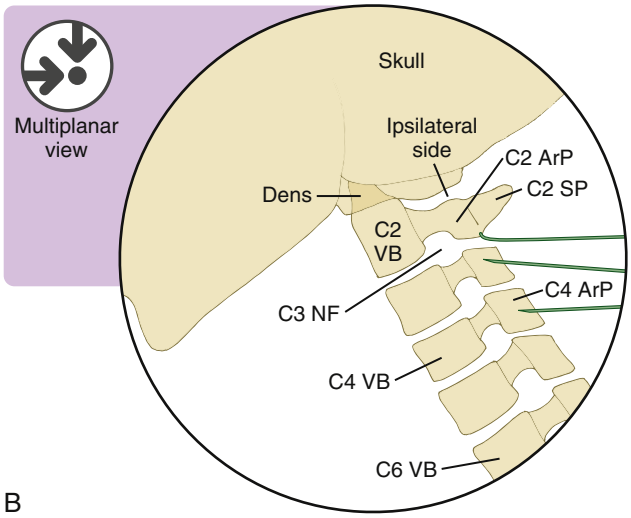
OPTIMAL NEEDLE POSITIONING IN THE IPSILATERAL FORAMINAL OBLIQUE VIEW (FIG. 30D.3)

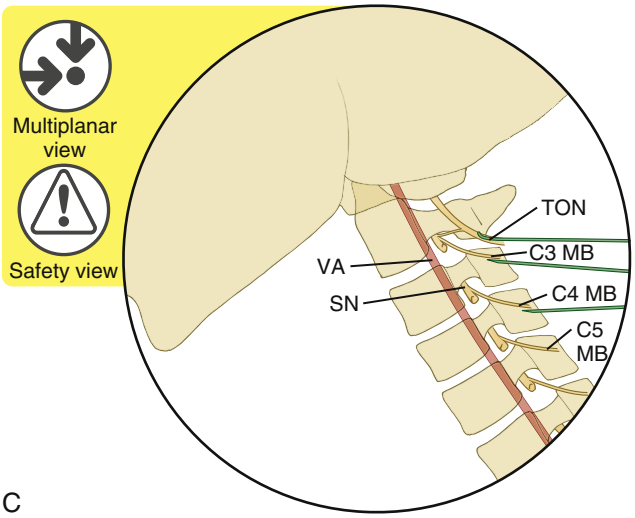
- The ipsilateral foraminal oblique view can be obtained to confirm correct needle placement or to guide the needle along the cervical medial branch (see Chapter 3, Fig. 3.19).
- This ipsilateral foraminal oblique view separates the ipsilateral and contralateral lateral masses from being superimposed on each other and allows for better visualization of the neural foramen (NF).
- The medial branches of interest are located posterior to the ipsilateral foramen.
- This view can be especially helpful with the lower medial branch blocks, especially the C7 medial branch block, when the lateral view may be obscured by superimposed shoulders or other radiopaque structures.

Notes on Obtaining the Ipsilateral Foraminal Oblique View

- Obtain a foraminal oblique view as described in Chapter 3.
- To best visualize the cervical medial branches of interest in this foraminal oblique orientation, tilt the image intensifier in the cephalad direction and optimize articular pillars visualization.







Foraminal Oblique View Safety Considerations

- Avoid the vertebral artery and exiting spinal nerve by ensuring that the needle tip remains posterior to the NF.

Fig. 30D.3. A, Fluoroscopic foraminal oblique view with the needles positioned to target the cervical medial branches of the upper third occipital nerve (TON) and the cervical medial branches of C3 and C4. **B,** Radiopaque structures, fluoroscopic foraminal oblique view. **C,** Radiolucent structures, fluoroscopic foraminal oblique view. The upper needle is shown approaching the more superior extent of C2-C3 (TON). For further clarification on obtaining this image, please see Chapter 3 and Fig. 3.19.

Optimal Images (Figs. 30D.4 to 30D.7)

Optimal Image

- Ideal flow should be nonvascular.
- With the AP view, the contrast should remain within the lateral bony groove at the location of the target medial branches (i.e., the waist of the articular pillar).
- With the lateral and contralateral oblique views, the contrast should remain on the target site (i.e., the articular pillar) at the location of the medial branch nerves.

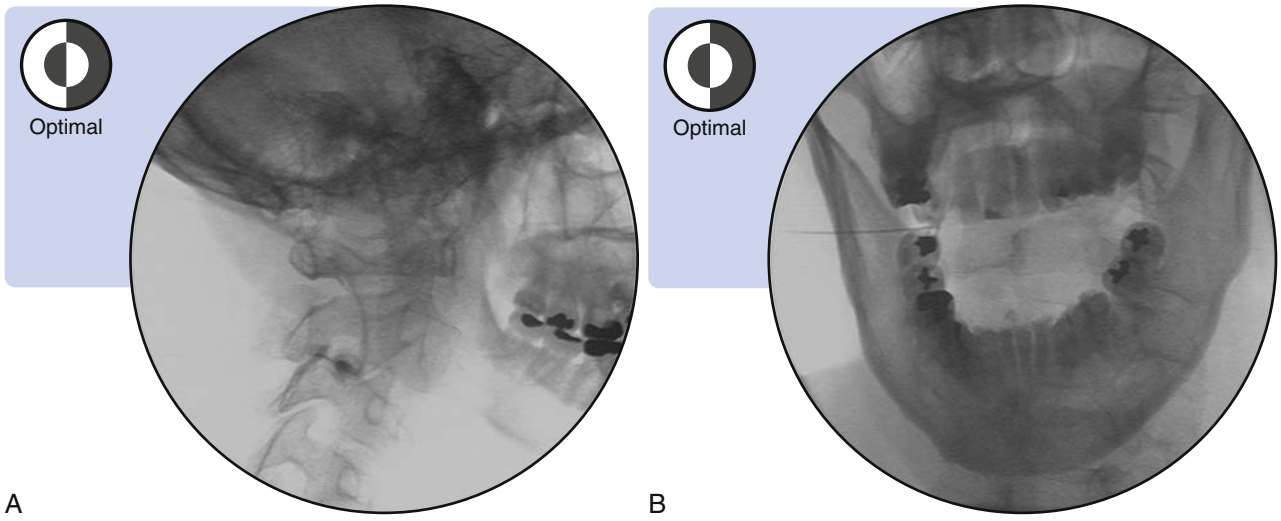


Fig. 30D.4. A, Ipsilateral foraminal oblique fluoroscopic image of a cervical medial branch block (third occipital nerve) with 0.5 cc of contrast. **B,** Anteroposterior image of a cervical medial branch block (third occipital nerve). The patient's mouth is open to improve visualization.

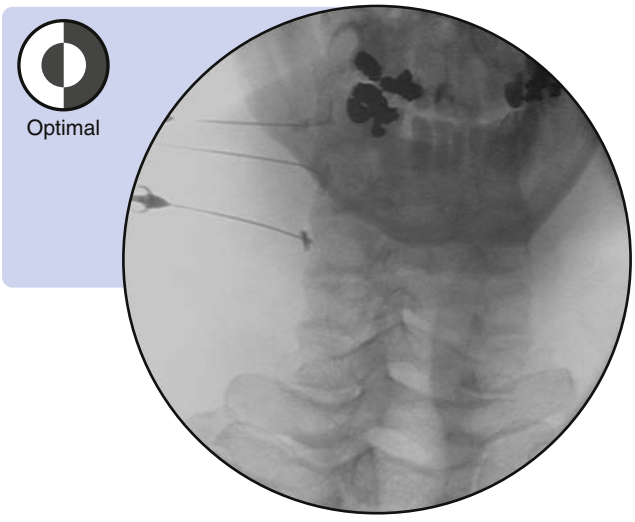


Fig. 30D.5. Anteroposterior fluoroscopic image of cervical medial branch blocks (C3, C4, and C5) with 1.5 cc of contrast (total volume, divided). Please note that at the C3 level, the initial contrast flow was suboptimal. The needle was advanced slightly with the use of the trajectory view to obtain optimal flow.

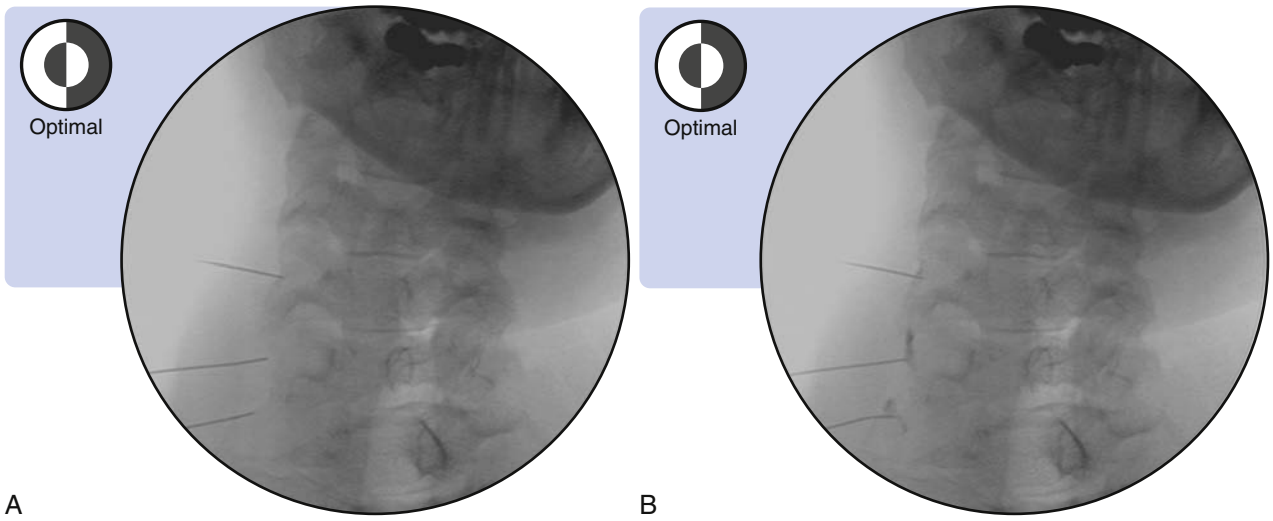


Fig. 30D.6. A, Anteroposterior fluoroscopic image of cervical medial branch blocks (C5, C6, and C7), precontrast image. **B,** Anteroposterior fluoroscopic image of cervical medial branch blocks (C5, C6, and C7), postcontrast image.

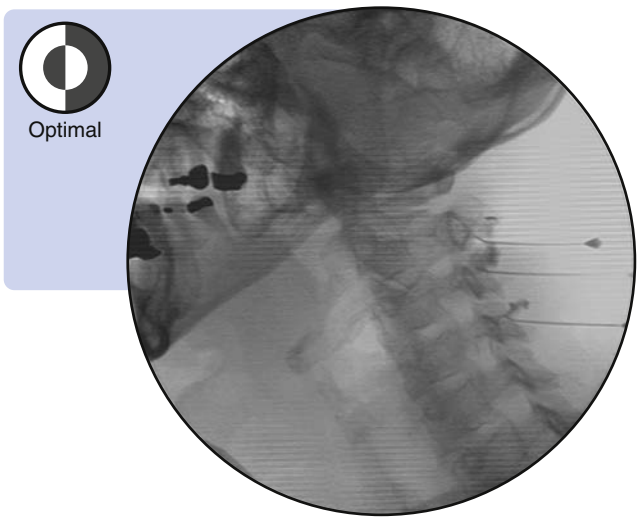


Fig. 30D.7. Ipsilateral foraminal oblique fluoroscopic image of cervical medial branch blocks of C3 and C4 with optimal flow. The upper needle is shown approaching the more superior extent of C2-C3 (third occipital nerve [TON]). There is residual contrast along the TON.

Suboptimal Images (Figs. 30D.8 to 30D.9)

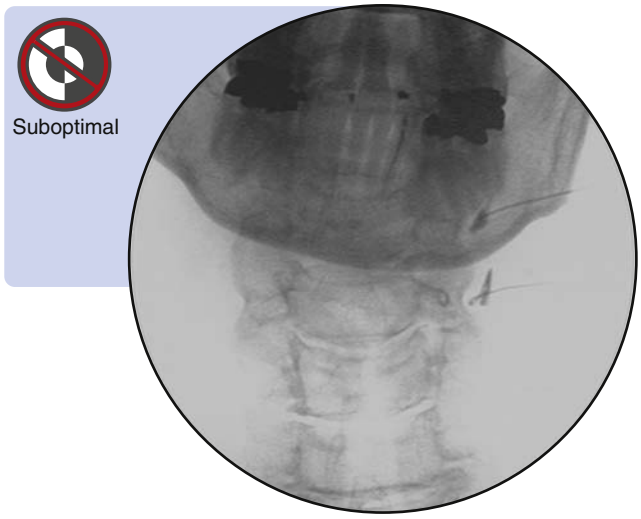


Fig. 30D.8. Anteroposterior fluoroscopic image of cervical medial branch blocks of C3 and C4 demonstrating contrast flow that is too far lateral and potentially not bathing the nerve location. The needles were then advanced further (not shown) to obtain an optimal image.

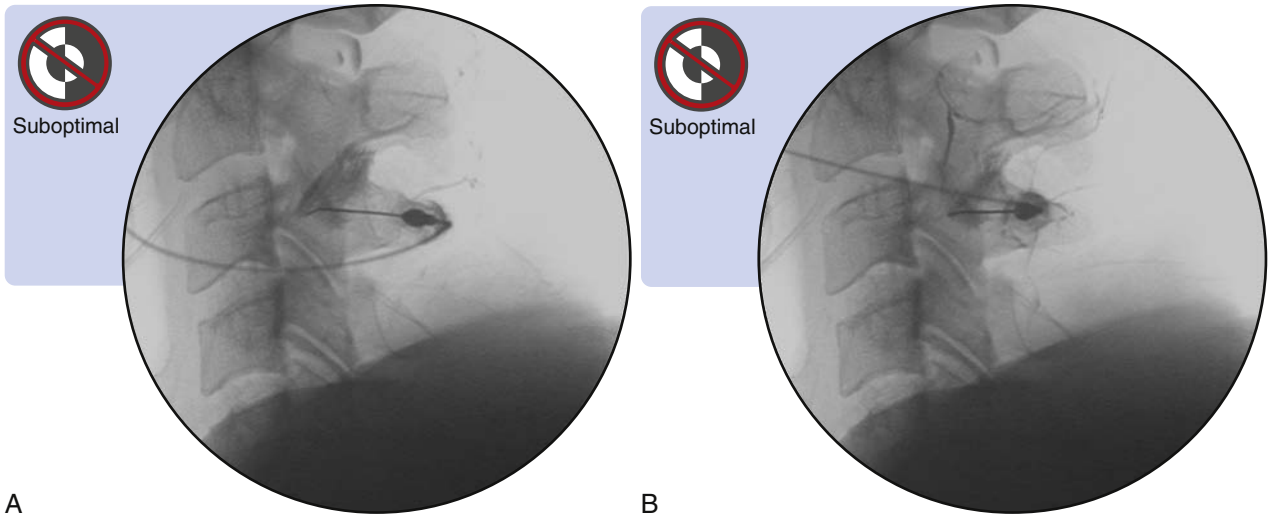


Fig. 30D.9. A, Lateral fluoroscopic image of a cervical medial branch block of C3. This is a static image taken several seconds after the contrast medium was placed. **B,** Image of the same area as shown in part **A** of this figure, but obtained under live fluoroscopy during contrast medium injection. The vascular uptake is immediately apparent.

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2. Bogduk N, ed. *Practice Guidelines for Spinal Diagnostic and Treatment Procedures*. 2nd ed. San Francisco: International Spine Intervention Society; 2013.
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CHAPTER 30E

Cervical Zygapophysial Intraarticular Injection—Posterior Approach: Ultrasound Guidance

Louis Torres, Simon J. Shapiro, Paul S. Lin, and Michael B. Furman

Cervical zygapophysial joints (Z-joints) can be safely, effectively, and efficiently accessed with ultrasound (US) guidance by an experienced interventionalist. The structures involved are relatively superficial and, thus, lend themselves well to US visualization. Furthermore, radiolucent structures that cannot be seen on fluoroscopy may be visualized on US, enhancing the safety of this intervention.

Here we present a posterior approach for cervical Z-joint intraarticular injection with an in-plane technique and out-of-plane confirmation. This technique can be used alone or in conjunction with conventional fluoroscopy in a hybrid technique, thus, eliminating or minimizing exposure to ionizing radiation.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 30E.1)

- The patient is side-lying, facing the US unit. The interventionalist is behind the patient (see Fig. 30E.1A).
- The US unit is positioned on the opposite side to the interventionalist and in line with the transducer (as described in Chapter 4).
- Utilize a linear transducer, as the structures of interest are relatively superficial.
- Identify the vertebral artery at C2 (see Chapter 4).
- Use the techniques described in Chapter 4 to identify and mark the target level.
- Start with the transducer in long axis to the cervical spine. Identify the facet joint and articular pillars.
- After identifying the target joint, rotate the transducer 90 degrees (short axis view of the cervical spine) (see Fig. 30E.1D).
- Stay over the target facet joint that is relatively **superficial and rounded** in comparison to the hyperechogenic adjacent articular pillars, which are slightly deeper and flatter.
- Translate the transducer anteriorly so that the targeted joint is close to the point of planned needle entry.
- Using an in-plane technique, insert the needle with a slightly oblique trajectory (posterolateral to anteromedial) and advance to the target joint (see all Figs 30E.1).

Fig. 30E.1. A, Suggested room, interventionalist, transducer, and US unit setup for side lying proceedure.

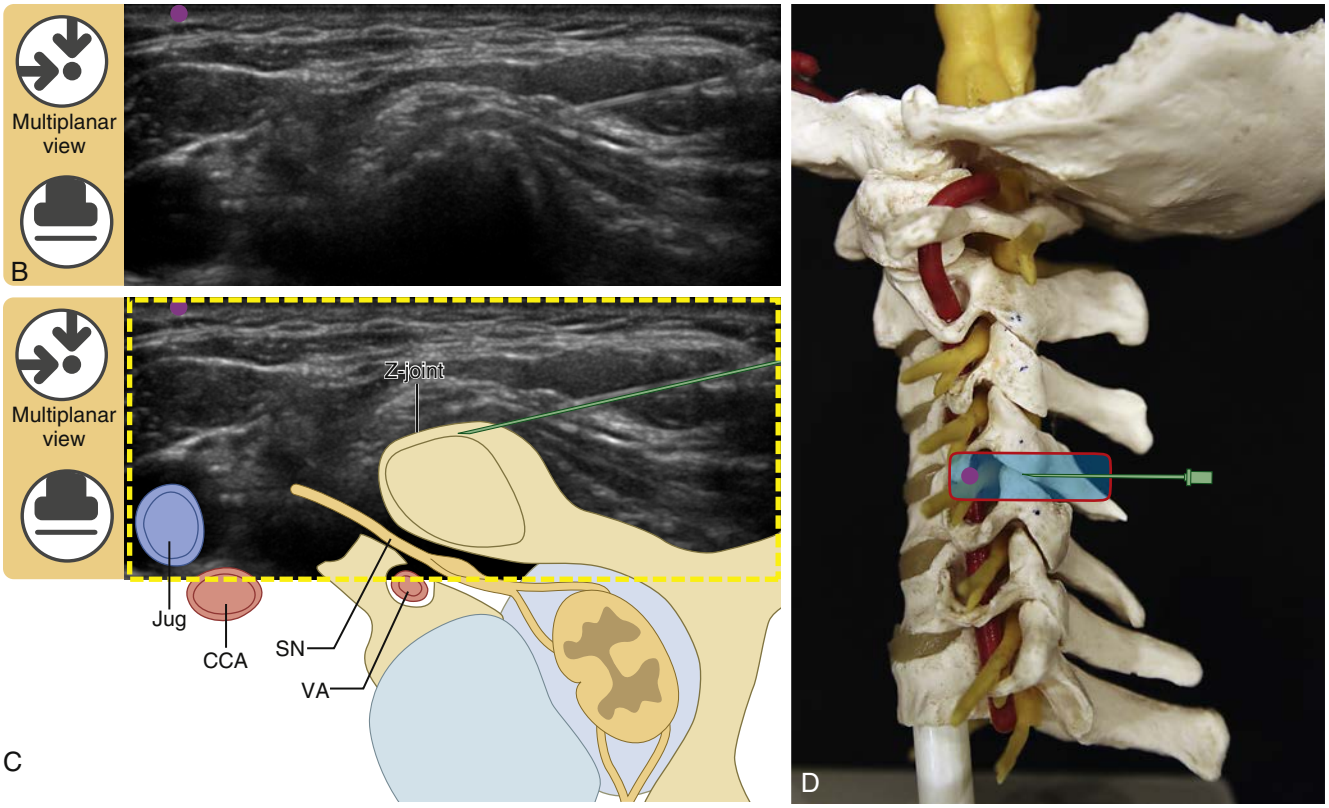

Fig. 30E.1. B, Ultrasound (US) image of in-plane needle placement at the targeted zygapophysial joint (Z-joint) with a posterior approach. Note the cortical irregularity and visualized Z-joint capsule. **C,** Drawing of relevant structures corresponding to Figure 30E.1A. Yellow dashed line represents borders of image seen on US in Figure 30E.1B. **D,** Proper placement of ultrasound transducer.

In-Plane Technique Safety Considerations

- Maintain direct visualization of the needle tip at all times.
- Avoid ventral excursion past the anterior border of the lateral mass to avoid contacting the spinal nerve.
- Avoid penetration completely through the facet joint, as the vertebral artery lies anteromedial to the joint (this is unlikely given the orientation of the joint).
- The common carotid artery (CCA) and jugular vein (Jug) are located anteriorly, but with proper setup, should not be in the needle's trajectory.

Out-of-Plane Confirmation (Fig. 30E.2)

- Rotate the transducer 90 degrees to obtain an out-of-plane confirmation view.
- Visualize the needle tip at the posterolateral aspect of the target facet joint (see Fig. 30E.2).
- If necessary, reposition the needle tip so that it is intraarticular.
- The shaft of the needle appears as a single dot, as demonstrated in Fig. 30E.2.
  - Needle bevel rotation or "jiggle" can help visualize the needle tip in the out-of-plane confirmation view.
  - The use of magnification can help identify subtle needle motion (as noted in Chapter 4).
- This is not a safety view. Instead, use an in-plane image for safe needle advancement to best visualize the corresponding landmarks.
- Use caution when using the out-of-plane view to reposition the needle.
- The needle appears as a dot on the US image. The dot may represent the tip or any part of the shaft of the needle.

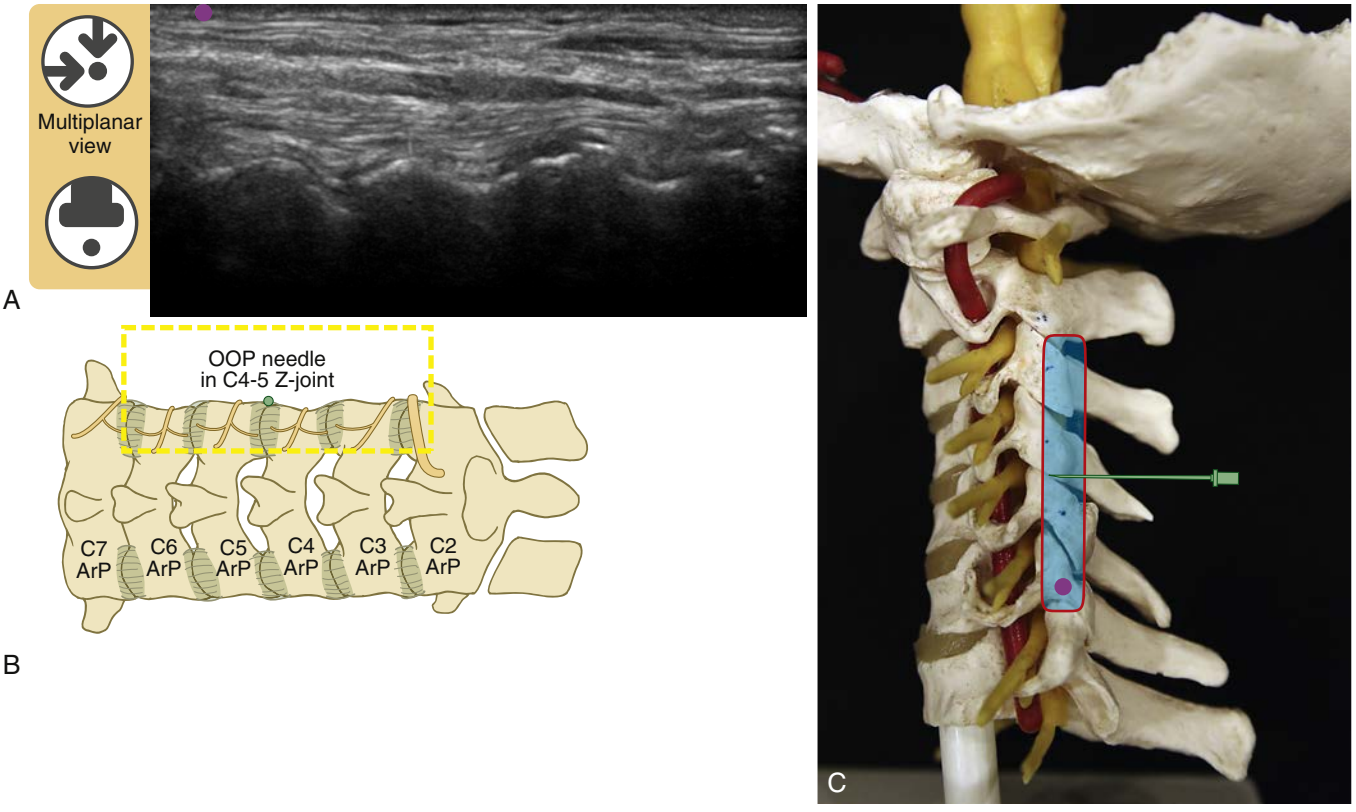

Fig. 30E.2. A, Ultrasound (US) image of out-of-plane needle placement at the targeted cervical zygapophysial joint. Note the peaks (targetted Z-joints) and troughs (articular pillars with medial branches). **B,** Drawing of relevant structures corresponding to Figure 30E.1A. Yellow dashed line represents borders of image seen on US in Figure 30E.2A. **C,** Proper placement of ultrasound transducer demonstrating 90-degree rotation from in-plane view.

Optimal Needle Placement and Image (Fig. 30E.3)

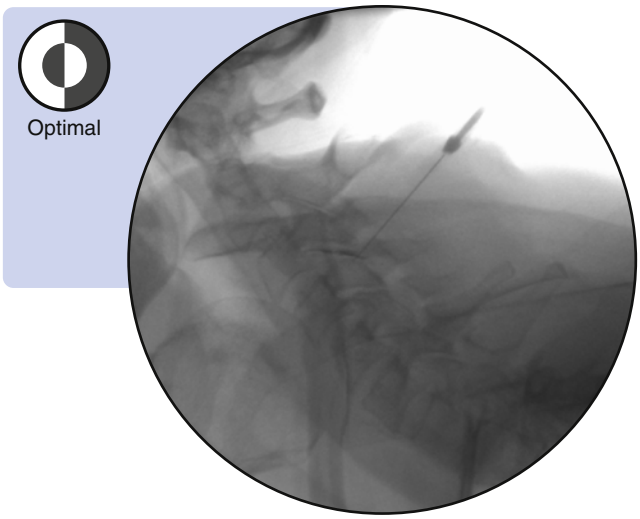

Fig. 30E.3. Lateral fluoroscopic view correlation after ultrasound-guided intraarticular cervical zygapophysial joint (Z-joint) injection (posterior approach). Note the optimal contrast pattern in the C3-C4 Z-joint.

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1. Spinner DA. Spine. In: Spinner DA, Kirschner JS, Herrera JH, eds. *Atlas of Ultrasound Guided Musculoskeletal Injections*. New York: Springer; 2013:123–137.
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Suggested Readings

Eichenberger U, Greher M, Kapral S, et al. Sonographic visualization and ultrasound-guided block of the third occipital nerve: prospective for a new method to diagnose C2-C3 zygapophysial joint pain. *Anesthesiology*. 2006;104(2):303–308.

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CHAPTER 30F

Cervical Zygapophysial Joint Nerve (Medial Branch) Radiofrequency Neurotomy and Nerve Injection, Posterior Approach: Fluoroscopic Guidance

Tejas N. Parikh, Isaac Cohen, Luis Baez-Cabrera, and Michael B. Furman

Cervical radiofrequency neurotomy (aka ablation, lesioning or denervation) (RFN) is typically performed after significant pain relief is documented with diagnostic medial branch blocks (MBB). The approach to cervical RFN is posterior. The electrode tip is placed so that the neurotomy occurs parallel to the nerve. Because there is anatomic variation with regard to the course of the medial branch (MB) nerve, many practitioners perform two to four denervations at each level. The practitioner must assess the size of the articular pillar (ArP) of the target zone and according to the size of the electrode utilized, calculate the amount of lesions required to fill the target zone with lesions.

In this chapter, we describe a pragmatic trajectory. Some (i.e., Spine Intervention Society[2]) recommend that both sagittal and oblique passes be performed at each segment, with the exception of the C7 MB, which requires only a sagittal pass. Electrode depths for sagittal and oblique passes differ, and tilt varies per segment targeted.

The third occipital nerve courses transversely across the lateral margin of the C2-C3 joint. The C8 MB location is similar to the T1-T3 MB nerves over the superolateral transverse process of the inferior level. (Frank Willard, PhD, Anatomist, personal communication) (see Thoracic Zygapophysial Joint [Facet] Procedures Chapters 22B and 22C).

This chapter focuses mostly on RFN; however, the same posterior approach, although less commonly used, is also suited for MBB. The final electrode-tip position differs for RFN versus MBB posterior approach. With RFN, the goal is to make lesions parallel to the entire accessible length of the MB as it winds its way around the curved ArP. The 30-degree oblique pass targets the MB associated with the anterior third of the pillar, and the parasagittal pass targets the MB associated with the mid third of the pillar. Thus, a more ventral electrode placement is utilized for the 30-degree oblique pass, and a more dorsal placement is utilized for the parasagittal pass.

This differs from a cervical MBB, where the needle tip should overlie the midpoint (centroid) of the pillar. With MB neurolysis, multiple lesions are created in a

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

zone, whereas the target for cervical MBB is a single point where the injectate volume is placed. In both procedures, the lesion zones or injectate volumes, respectively, encompass the known variable locations of the targeted nerves.

When cervical RFN is performed, the electrode is placed using a trajectory view and advanced using multiplanar imaging, with an emphasis on safely using the lateral and contralateral (foraminal) oblique (see Chapter 3) views to confirm the depth. After electrode depth location is confirmed and just prior to denervation, 0.5 to 1 cc of anesthetic is injected through the electrode to anesthetize the MB, periosteum, and soft tissues. The time and duration of the denervation vary with different practitioners (e.g., two to four 90-second cycles at 80°C to 85°C).

Special attention should be paid to Chapter 30H, which illustrates the variability of the cervical MB nerves' anatomic courses and demonstrates recommended RF electrode positions and lesion "zones."

Third Occipital Nerve Trajectory View (Fig. 30F.1)

Confirm the C2-C3 level (with the anteroposterior [AP] view).
Use almost no C-arm image intensifier tilt, and identify the C2-C3 joint.
Oblique the C-arm image intensifier 30 degrees toward the symptomatic side (the left side, in this case).

- This angle is used for entry.
- The electrode-tip destination is the nerve location along the lateral C2-C3 joint margin.
- The final/electrode positions are based on the variability of the nerve as shown in the anatomy diagrams in Chapter 30H.

Because this is the trajectory view, the electrode entry position should be parallel to the C-arm beam.

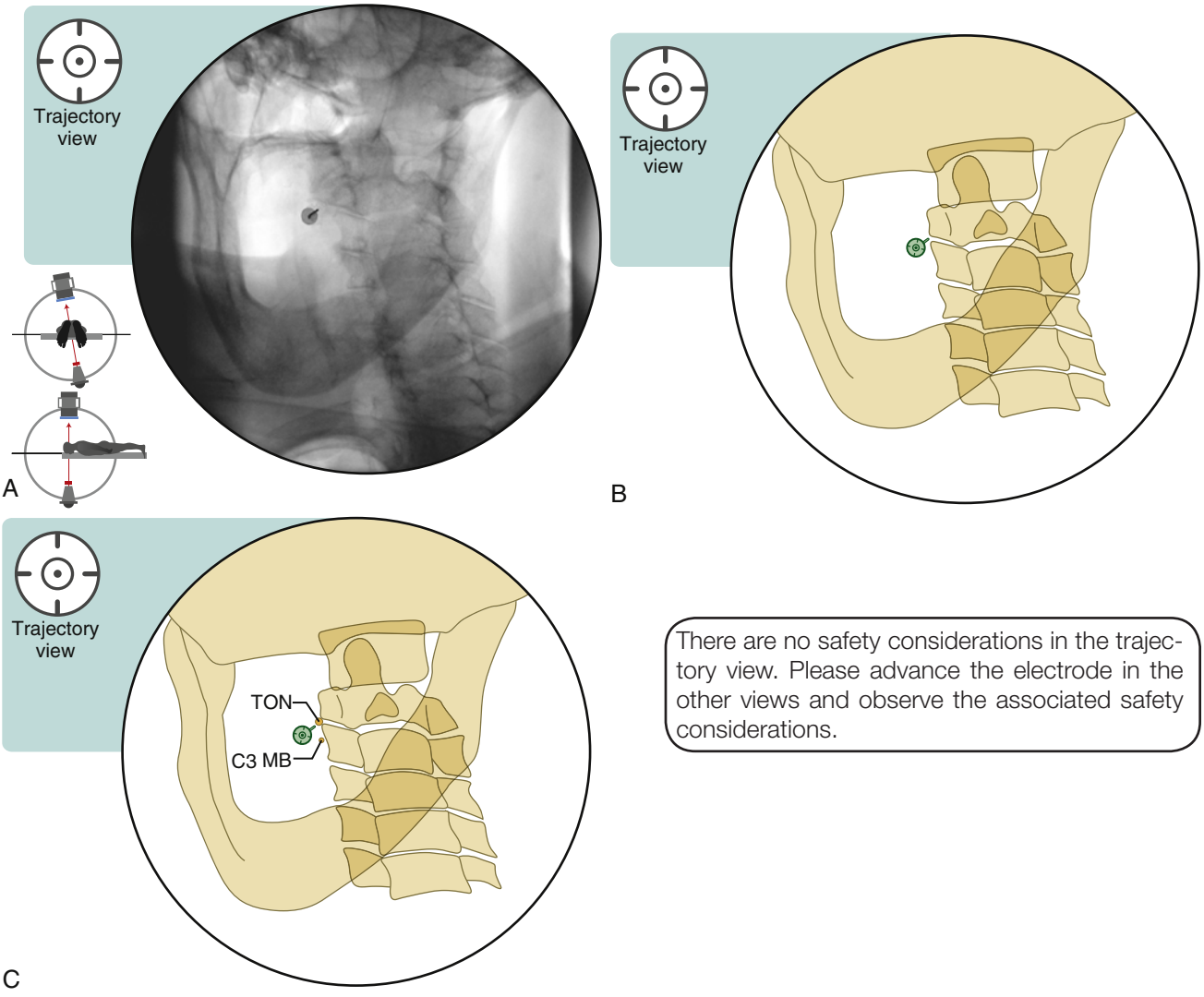


Fig. 30F.1. A, Fluoroscopic image of a trajectory view with the electrode tip in position over the left third occipital nerve innervating the C2-C3 joint. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view. See Chapter 30H diagrams for the variable anatomic course of the cervical medial branch nerves.

C3, C4, C5, and/or C6 Medial Branch Trajectory View (Fig. 30F.2)

Confirm the level (with the AP view).
Tilt the C-arm image intensifier caudally until the Z-joints "open" for the targeted segment. This orients the trajectory parallel to the plane of the Z-joint and also helps identify the lateral groove or "waist" of the ArP (i.e., the lateral mass).
Oblique the C-arm image intensifier 30 degrees toward the symptomatic side (the left side, in this case).

- This angle is used for entry.
- The electrode-tip destination is the lateral groove or "waist" of the ArP.
- There is variation with regard to the final electrode position that is based on the level that is being treated.
- In this chapter, we describe a pragmatic oblique pass. The other recommended technique includes both sagittal and oblique passes at each level.
- The C5 MB lies within the middle segment of the lateral groove or "waist" of the ArP.
- Moving away from the C5 level in the cephalad and caudad directions results in a more superior location of the MB within the lateral groove or "waist" of the ArP (see Figs. 30H.1 and 30H.2).

Because this is the trajectory view, the electrode entry position should be parallel to the C-arm beam.

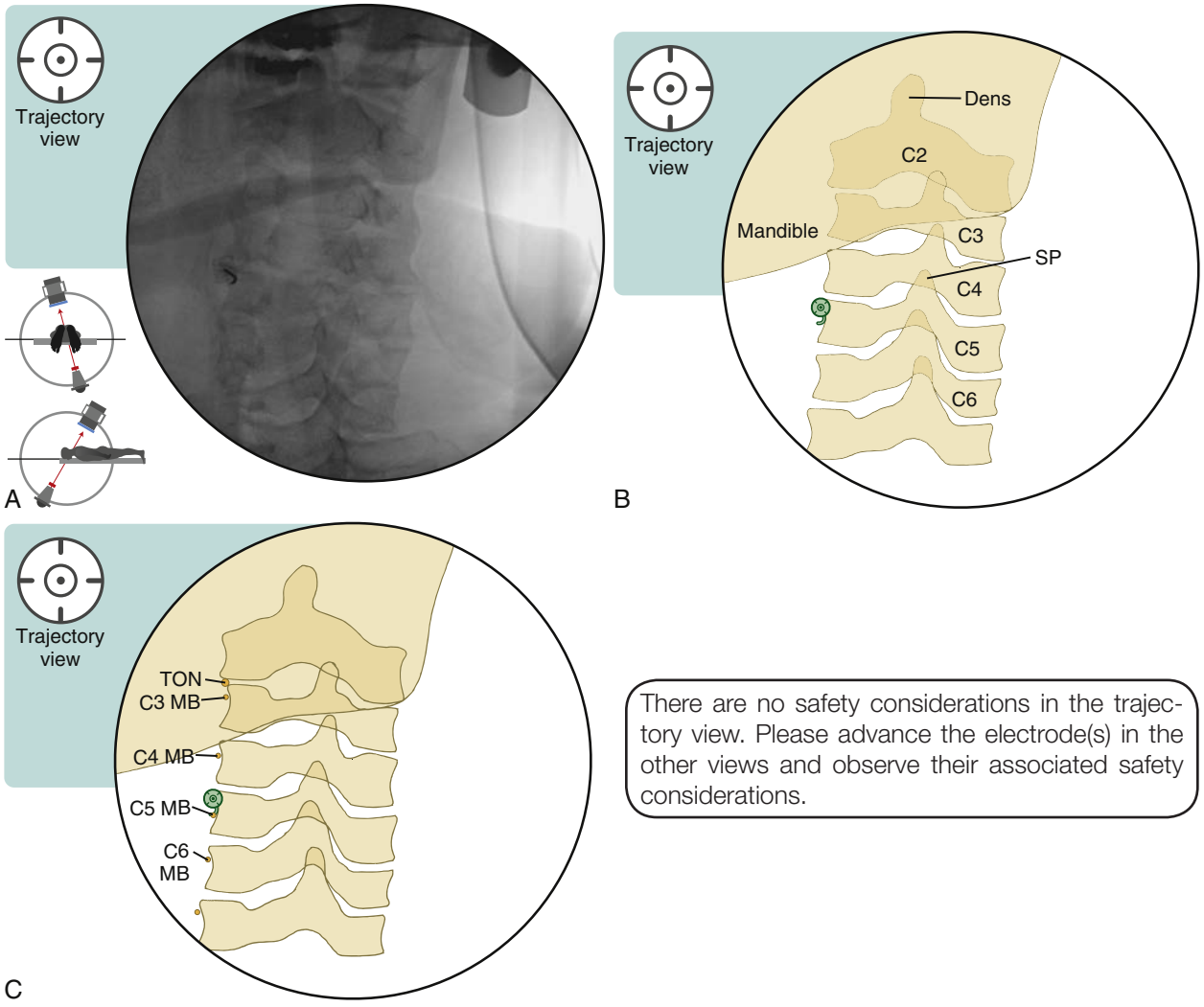


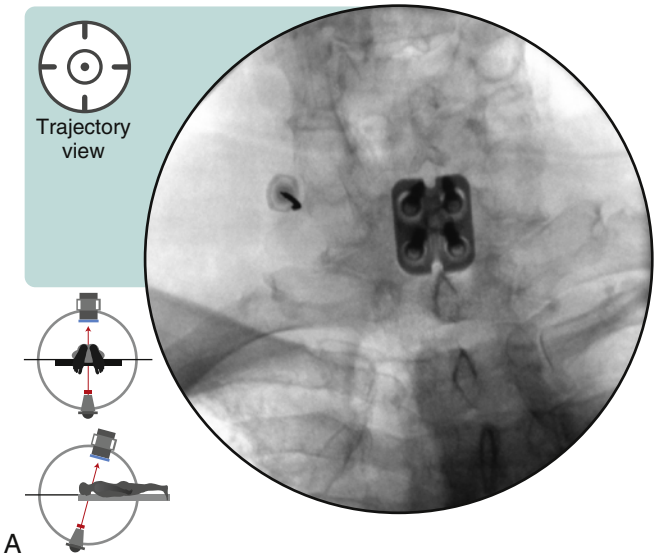
Fig. 30F.2. A, Fluoroscopic image of a trajectory view with the electrode tip in position over the left C5 medial branch nerve. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view. This figure illustrates the location of the middle cervical medial branch nerve courses. See Chapter 30H diagrams for the variable anatomic course of the cervical medial branch nerves.

C7 Medial Branch Trajectory View (Fig. 30F.3)

Confirm the C7 level (with the AP view).
Tilt the C-arm image intensifier slightly caudally to identify the C7 superior articular process (SAP)/transverse process junction.
Keep the C-arm image intensifier without any oblique (0 degrees oblique).

- This angle is used for entry.
- The electrode-tip destination is at the junction of the C7 SAP and transverse process. The RF zone for C7 MBN extends from the apex of the C7 SAP to the base of the SAP/proximal-most aspect of the transverse process (see Fig. 30H.1).
- For C7, use appropriate tilt and a sagittal pass to best visualize the target (without oblique).

Because this is the trajectory view, the electrode entry position should be parallel to the C-arm beam.



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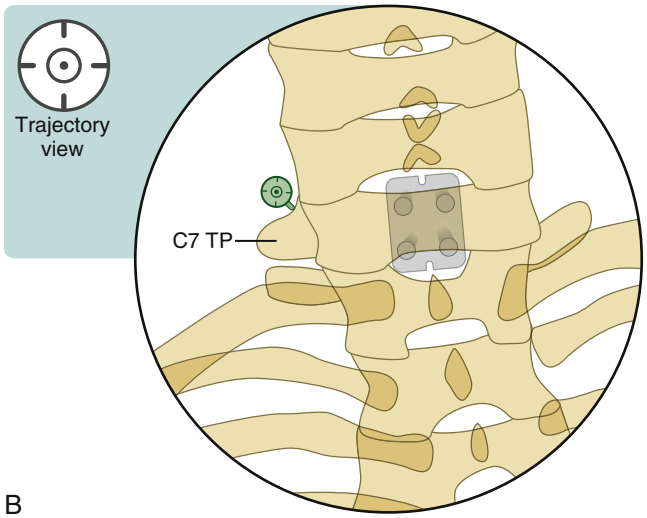
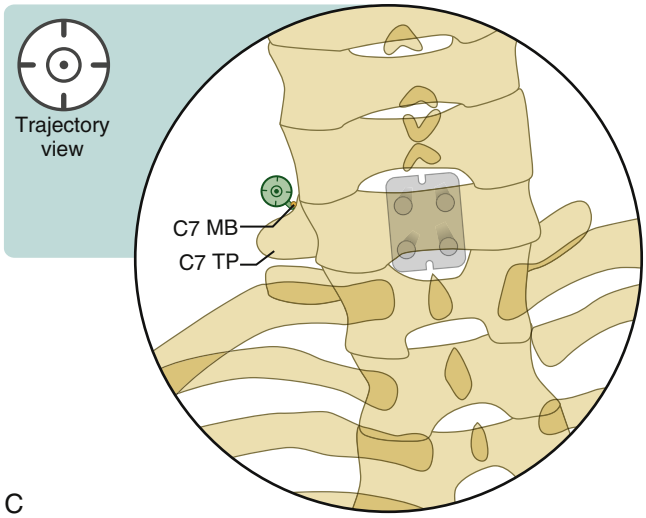


B



C

There are no safety considerations in the trajectory view. Please advance the electrode in the other views and observe the associated safety considerations.

Fig. 30F.3. A, Fluoroscopic image of a trajectory view with the electrode tip in position over the left C7 medial branch nerve. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view. See Fig. 30H.1 for the variable anatomic course of the cervical medial branch nerves.

C8 Medial Branch Trajectory View (Fig. 30F.4)

The C8 MB location is similar to the thoracic-level MB nerves over the superolateral transverse process of the inferior level.

Confirm the T1 level (with the AP view).
Tilt the C-arm image intensifier 0 to 10 degrees caudally.
Oblique the C-arm image intensifier 10 degrees contralaterally from the AP view so that the RF electrode is placed parallel to the course of the C8 MB nerve.

- This angle is used for entry.
- The electrode-tip destination is the superolateral corner of the T1 transverse process.

Because this is the trajectory view, the electrode entry position should be parallel to the C-arm beam.

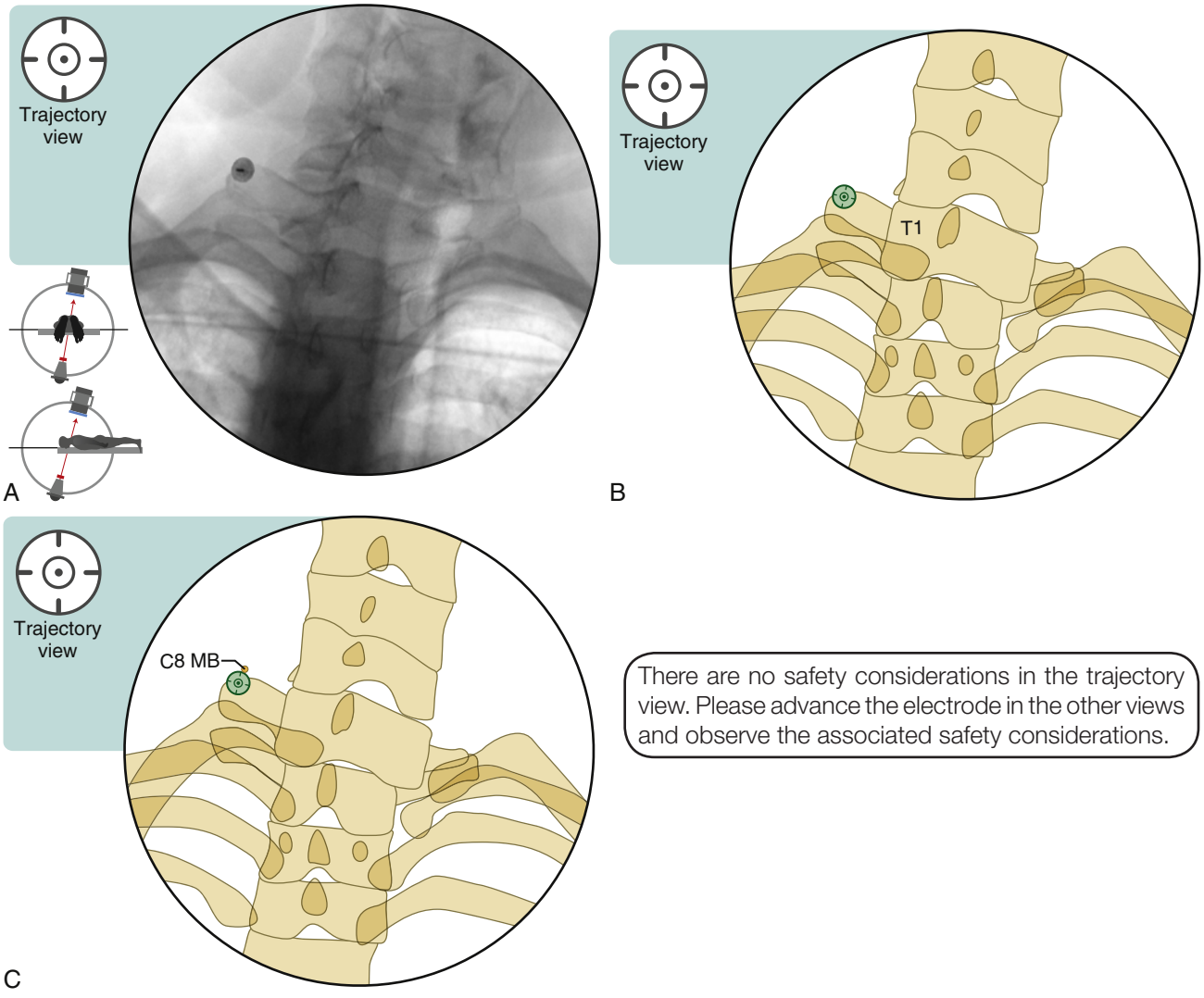


Fig. 30F.4. A, Fluoroscopic image of a trajectory view with the electrode tip in position over the left C8 medial branch nerve. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view. This figure illustrates the C8 medial branch nerve course. Note that the C8 medial branch nerve course is similar to that of the upper thoracic medial branches over the superolateral transverse process of the inferior level. See Fig. 30H.1 for the variable anatomic course of the cervical medial branch nerves.

Optimal Electrode Position in Multiplanar Imaging

For radiofrequency denervation, as the electrode tip reaches its target according to the trajectory views described above, three other views (i.e., AP, lateral, and contralateral [foraminal] oblique) are obtained for the final placement and confirmation of the electrode-tip position before stimulation and denervation.

- When performing RFN, the goal is to make lesions along the nerve and a zone along the entire length of the MB and its known potential course as it winds around a curved ArP. The 30-degree oblique pass allows better targeting of the anterior third of the nerve, and a parasagittal pass (not shown) can better target the MB associated with the mid third of the pillar.
- Diagnostic MB blocks attempt to target the midpoint of the centroid. Because the injectate is placed, it covers a different "volume" and shape than a radiofrequency procedure.
- Please see chapter 30H for diagrams and figures depicting the position of the MBs and associated neurotomy electrode positions and lesion zones in multiple views.

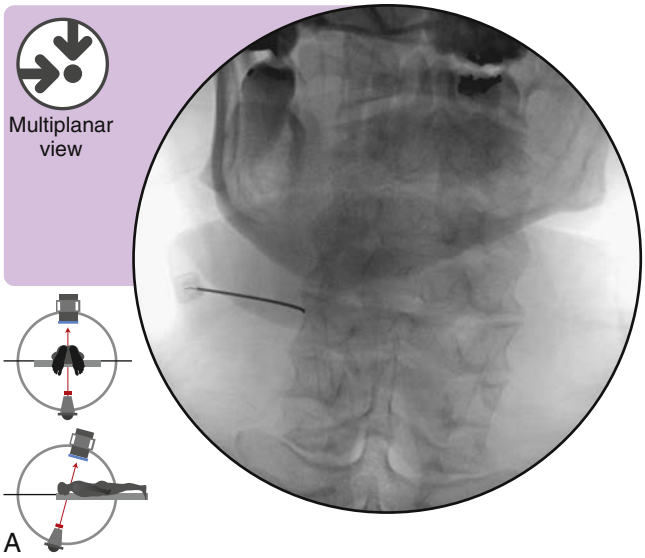
Please note that the RF zone attempts to treat all potential locations where the MB is known to lie.

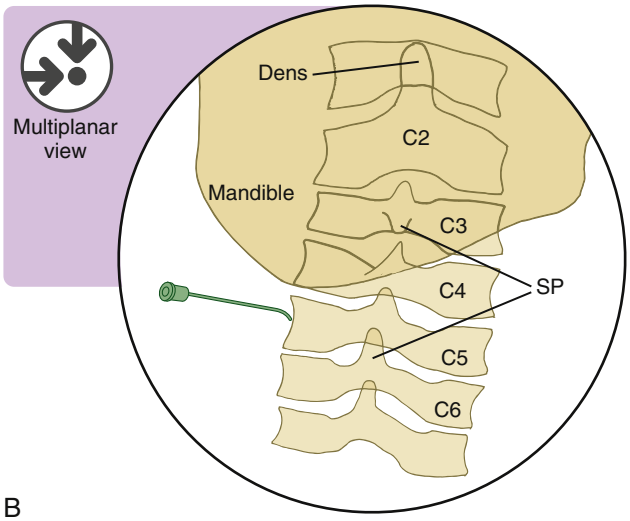
Notes on Electrode Positioning in the Multiplanar Views

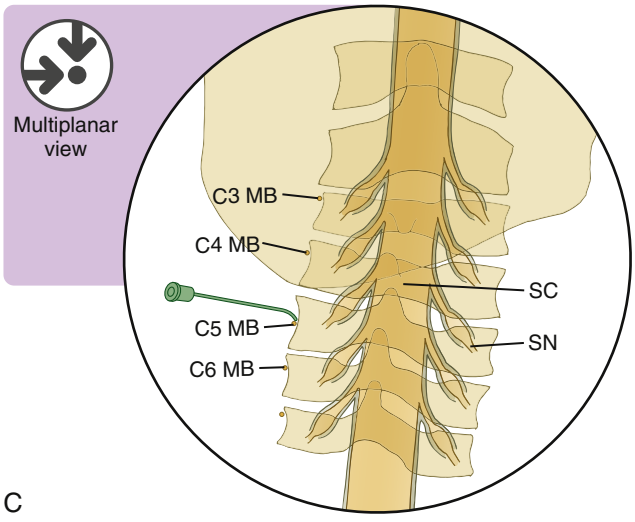
Please see chapter 30H for diagrams and images depicting the position of the MBs and associated neurotomy electrode positions and lesion zones in multiple views.

OPTIMAL ELECTRODE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 30F.5)

Use the AP view to confirm that the electrode tip is placed at the lateral margin of the C2-C3 joint. For C3-C6 MBs, confirm that the electrode tip is at the lateral groove or "waist" of the ArP. The AP view is actually a "pillar view" achieved by tilting to optimally view the ArPs. For C7 MB, confirm that the electrode tip is adjacent to the C7 superior articular process and proximal transverse process. The AP view is actually a "pillar view" achieved by tilting to optimally view the ArPs/lateral masses. The C8 MB nerve is treated similar to the thoracic MBs (see Chapters 22B and 22C).







Anteroposterior (AP) View Safety Considerations

Although unlikely, avoid medial stray of the electrode tip toward the spinal canal and potential spinal cord or spinal nerve (SN) contact.

- Using a single pragmatic oblique pass, the electrode tip should appear slightly medial to the lateral margin of the ArP as seen on the AP view, having been positioned along the curved ventral portion of the pillar.

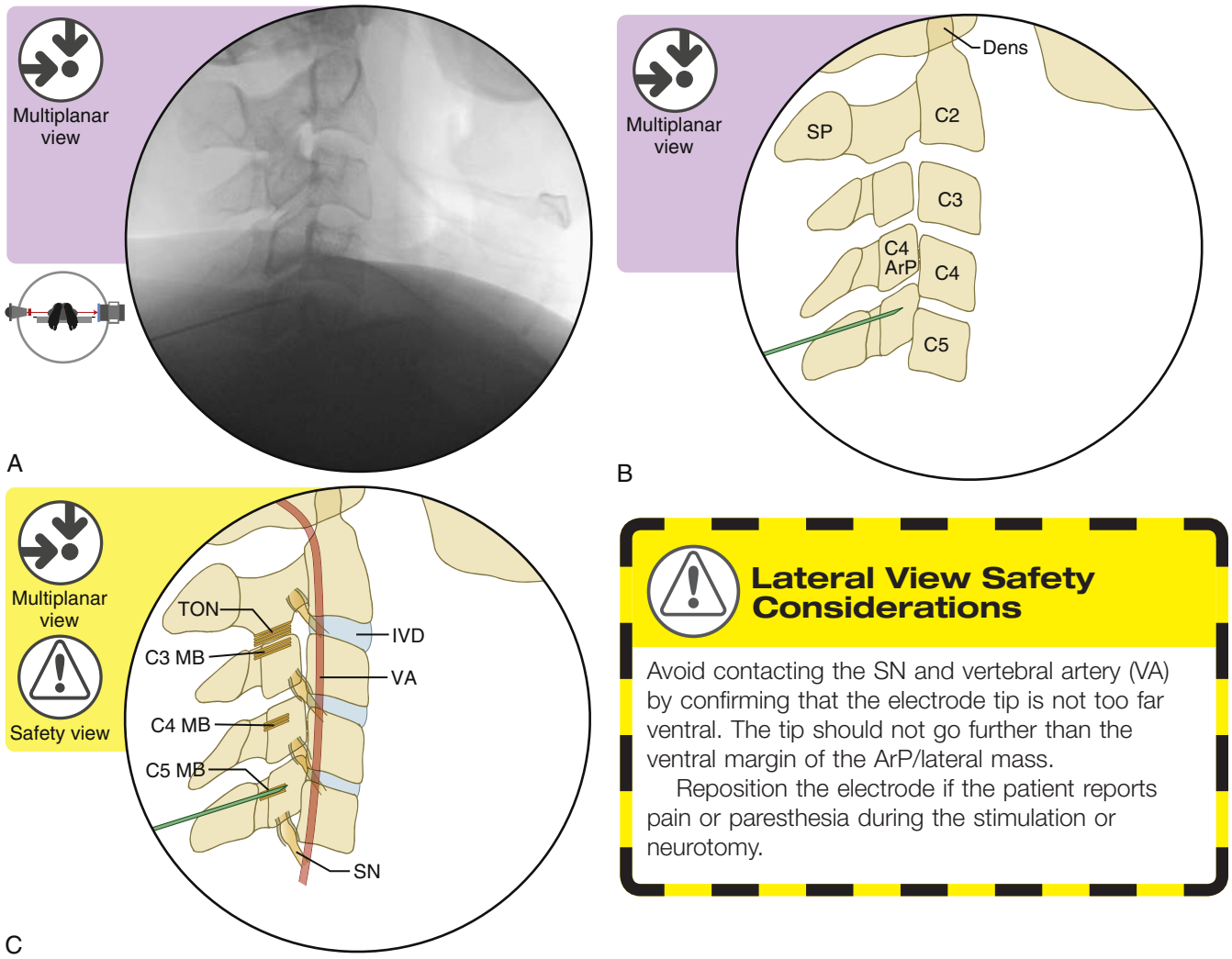
The electrode tip should NEVER stray medial to the medial margin of the pillar.

- Reposition the electrode if the patient reports pain or paresthesia during the stimulation or neurotomy. Always check multiplanar views, especially if this occurs.

Fig. 30F.5. A, Fluoroscopic image of an anteroposterior view with the electrode tip in position over the left C5 medial branch nerve during the performance of an oblique pass. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view. This figure illustrates a single location of the cervical medial branch nerves. See Fig. 30H.1 for the variable anatomic course of the cervical medial branch nerves.

OPTIMAL ELECTRODE POSITIONING IN THE LATERAL VIEW (FIG. 30F.6)

- The C-arm should be oriented to obtain a "true" lateral view (see Chapter 3).
- In a true lateral view, the electrode tip should not be positioned more ventral than the ventral margin of the ArP.



Lateral View Safety Considerations

Avoid contacting the SN and vertebral artery (VA) by confirming that the electrode tip is not too far ventral. The tip should not go further than the ventral margin of the ArP/lateral mass.

Reposition the electrode if the patient reports pain or paresthesia during the stimulation or neurotomy.

Fig. 30F.6. A, Fluoroscopic image of a lateral view with the electrode in position over the left C5 medial branch nerve. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view. The yellow lines simply represent the multiple locations of electrode placement due to the anatomic variability of each medial branch nerve. Fig. 30H.1 outlines the variable course of the cervical medial branch nerves. In this chapter, we describe an oblique pass. The recommended technique includes both sagittal and oblique passes at each level by varying the obliquity and tilt except for C7, which only requires a sagittal pass. The number of lesions performed with each pass is variable with at least three lesions made at each level except two lesions at C5 and four lesions at the third occipital nerve and C7. This is variable depending upon the size of the electrode used and the height of the superior articular process. The electrode placement between subsequent lesions should be no further apart than one electrode width.

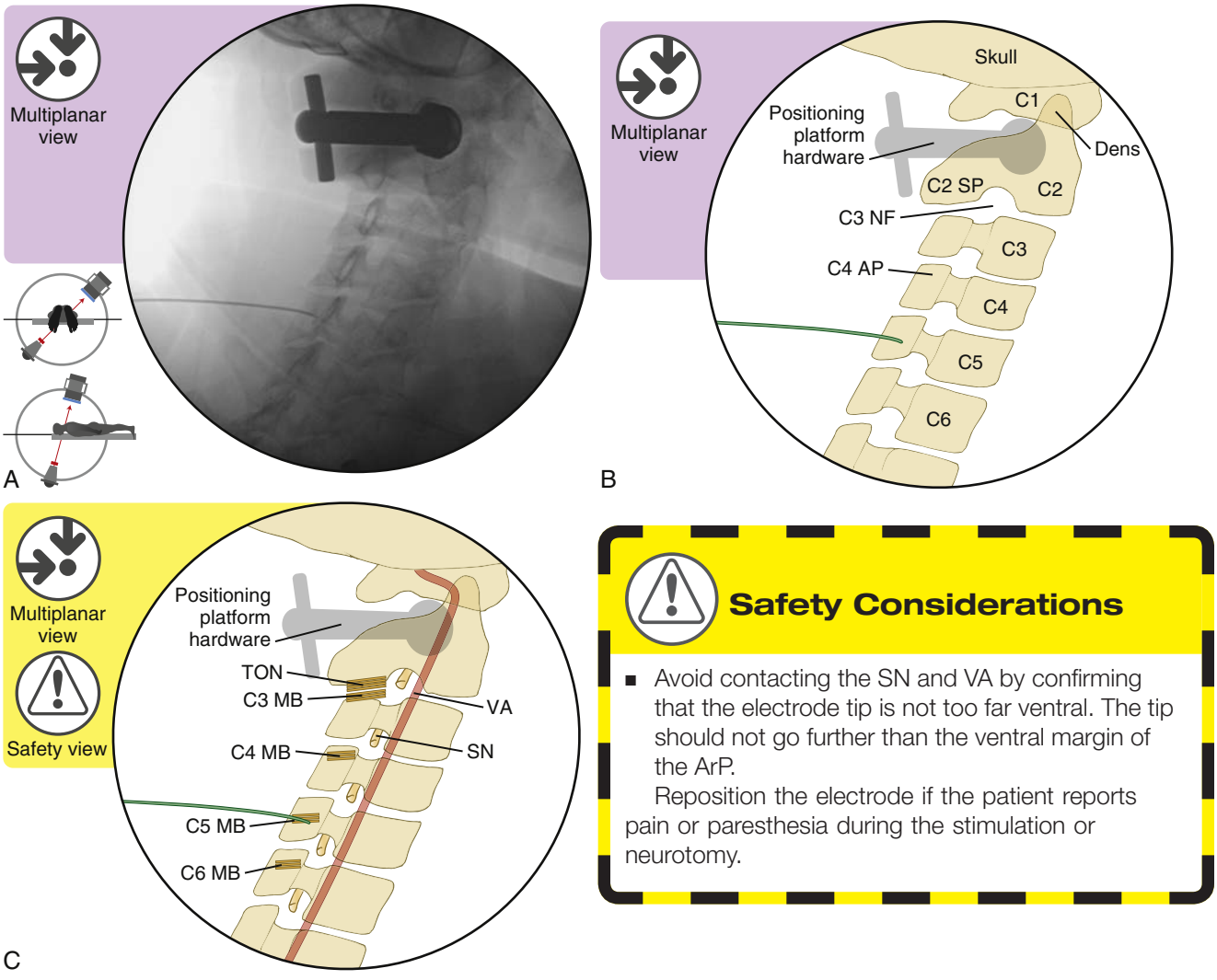
OPTIMAL ELECTRODE POSITIONING IN THE CONTRALATERAL OBLIQUE (FORAMINAL OBLIQUE) VIEW (FIG. 30F.7)

- The contralateral oblique view can be obtained to confirm the correct electrode placement and/or to guide the electrode along the cervical MB (see Chapter 3). The MBs of interest are located posterior to the ipsilateral foramen.

Notes on Obtaining the Contralateral Oblique View

Obtain a contralateral oblique view by visualizing the ipsilateral foramina as described in Chapter 3, Fig. 3.18.

To best visualize the cervical MB locations of interest in a contralateral oblique orientation, tilt the image intensifier in the caudad direction (see Chapter 3, Fig. 3.18).



Safety Considerations

- Avoid contacting the SN and VA by confirming that the electrode tip is not too far ventral. The tip should not go further than the ventral margin of the ArP.

Reposition the electrode if the patient reports pain or paresthesia during the stimulation or neurotomy.

Fig. 30F.7. A, Fluoroscopic image of a contralateral (foraminal) oblique view with the electrode in position over the left C5 medial branch nerve. **B,** Radiopaque structures, contralateral oblique view. **C,** Radiolucent structures, contralateral oblique view. The yellow lines simply represent the multiple locations of electrode placement because of the anatomic variability of each medial branch nerve. Fig. 30H.1 outlines the variable course of the cervical medial branch nerves. In this chapter, we describe an oblique pass. The recommended technique includes both a sagittal and oblique pass at each level by varying the obliquity and tilt except for C7, which only requires a sagittal pass. The number of lesions performed with each pass is variable, with at least three lesions made at each level except two lesions at C5 and four lesions at the third occipital nerve and C7. This is variable depending upon the size of the electrode used and the height of the superior articular process. The electrode placement between subsequent lesions should be no further apart than one electrode width.

Optimal Position Views (Figs. 30F.8 and 30F.9)

Electrode positioning parallel to the target MB nerve and lesioning the maximal length of its accessible portion is critical for success.

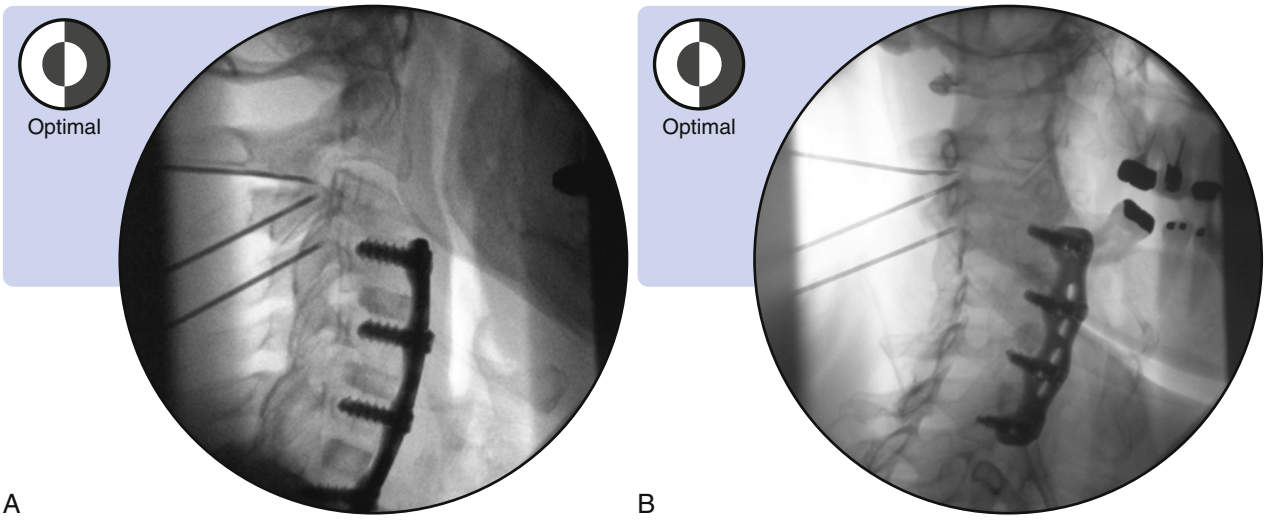


Fig. 30F.8. A, Fluoroscopic image of a lateral view with the electrode in position over the left third occipital, C3, and C4 medial branch nerves. **B,** Contralateral (foraminal) oblique view. Note the angle differences between the C3 and C4 medial branch electrode placements versus the third occipital nerve electrode placement.

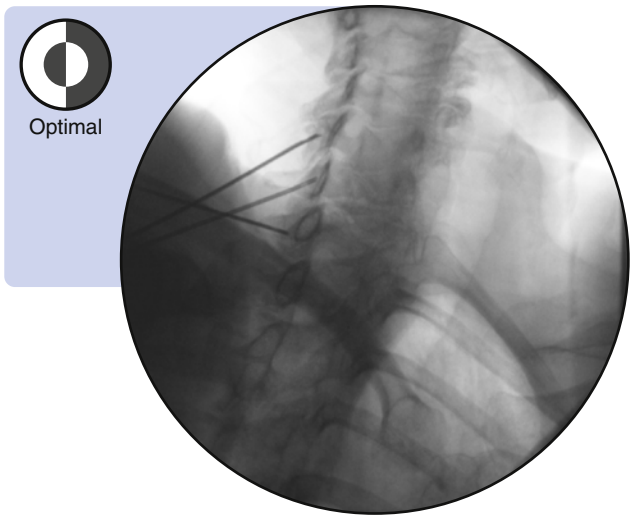


Fig. 30F.9. Fluoroscopic image of a contralateral (foraminal) oblique view with the electrodes in position along the left C5, C6, and C7 medial branch nerves. Note the angle differences between the C5 and C6 medial branch electrode placements versus the C7 medial branch electrode placement.

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CHAPTER 30G

Cervical Zygapophysial Joint Nerve (Medial Branch) Radiofrequency Neurotomy/Injection—Posterior Approach: Ultrasound Guidance

Louis Torres, Simon J. Shapiro, Paul S. Lin, and Michael B. Furman

Cervical facet/zygapophysial joint (Z-joint) nerves (medial branches) can be safely, effectively, and efficiently accessed with ultrasound (US) guidance by an experienced interventionalist. The structures involved are relatively superficial and, thus, lend themselves well to US visualization. Furthermore, radiolucent structures that cannot be seen on fluoroscopy may be visualized on US, enhancing the safety of this intervention.

Here we present a posterior approach for cervical medial branch block or radiofrequency neurotomy with an in-plane technique with out-of-plane confirmation. This technique can be used alone or in conjunction with conventional fluoroscopy in a hybrid technique, thus, eliminating or minimizing exposure to the ionizing radiation.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 30G.1)

- The patient is side-lying, facing the US unit. The interventionalist is behind the patient (see Fig. 30G.1A).
- The US unit is positioned on the opposite side to the interventionalist and in line with the transducer (as described in Chapter 4).
- Utilize a linear transducer, as the structures of interest are relatively superficial.
- Identify the vertebral artery (VA) at C2 (see Chapter 4).
- Use the techniques described in Chapter 4 to identify and mark the target level.
- Start with the transducer in long axis to the cervical spine. Identify the facet joints and articular pillars that appear respectively as peaks and troughs. (Fig 30G.1 B,C).
- After identifying the target level, rotate the transducer 90 degrees (short-axis view of the cervical spine) (see Fig. 30G.1D).
- Stay over the hyperechogenic articular pillar that is slightly deeper and flatter in contrast to the adjacent facet joint capsules, which appear rounded, peaked, and superficial in comparison. The medial branch nerve is located at the trough on the articular pillar between the facet joints (peaks).
- Translate the transducer anteriorly so that the targeted structure is closer to the point of planned needle entry.
- Using an in-plane technique, insert the needle with a slightly oblique trajectory (posterolateral to anteromedial) and advance to the target.

Fig. 30G.1A, Suggested room, interventionalist, transducer, and US unit set up for side lying procedure.

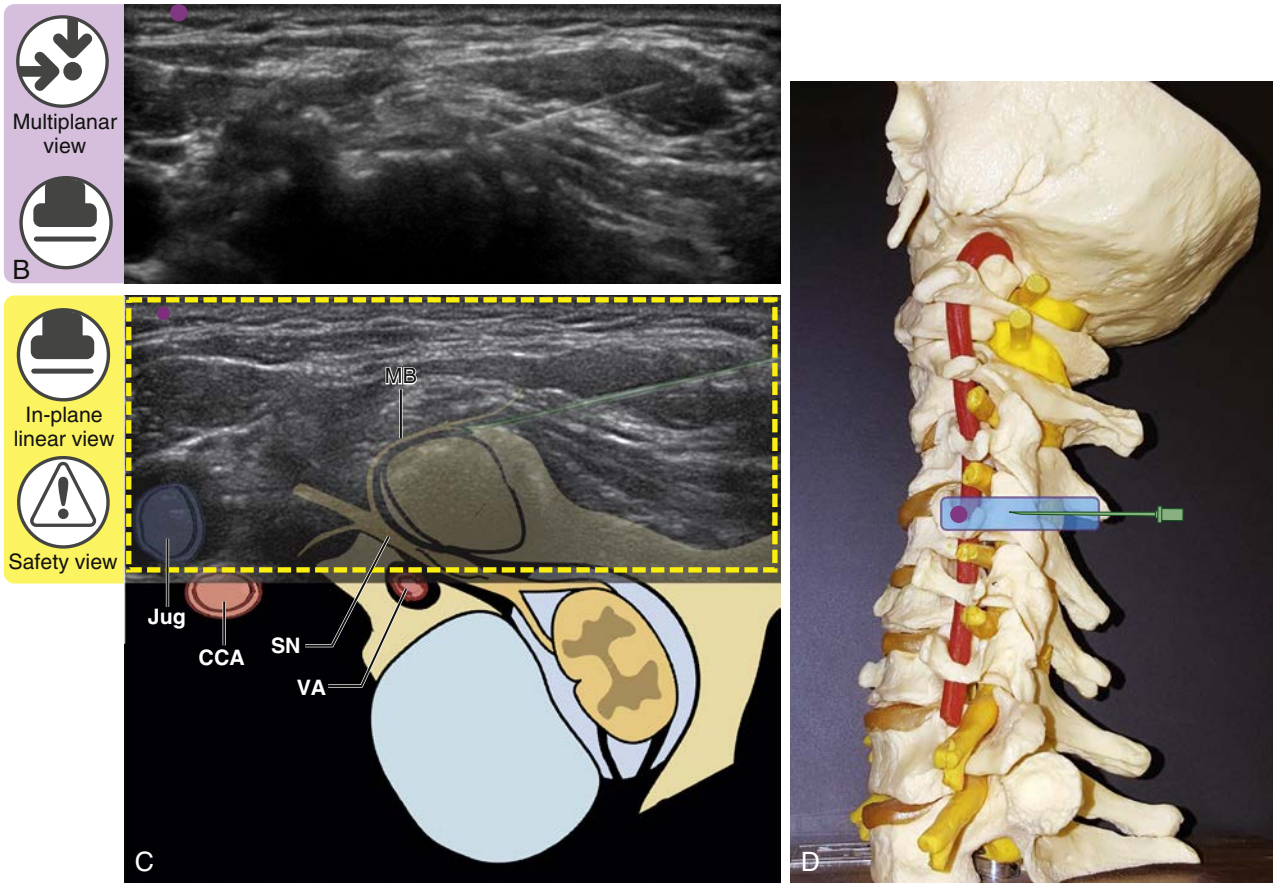

Fig. 30G.1, cont'd B, Ultrasound (US) image of in-plane needle placement at the targeted medial branch on the articular pillar. **C,** Drawing of relevant structures corresponding to Fig. 30G.1B. Yellow dashed line represents US image borders seen in Fig. 30G.1B. **D,** Proper US transducer placement.

In-Plane Technique Safety Considerations

- Maintain direct visualization of the needle tip at all times.
- Avoid ventral excursion past the anterior border of the lateral mass to avoid contacting the spinal nerve (SN).
- Avoid medial excursion to avoid the Z-joint and deeper structures including the VA.
- The common carotid artery (CCA) and jugular vein (JV) are located anteriorly, but with proper setup, should not be in the needle's trajectory.

Out-of-Plane Confirmation (Fig. 30G.2)

- Rotate the transducer 90 degrees to obtain an out-of-plane confirmation view.
- Visualize the needle tip on periosteum at the target location on the articular pillar (trough) between the facet joints (peaks) (see Fig. 30G.2).
- If necessary, reposition the needle tip so that it is at the desired level on the articular pillar. The ideal target is at the trough on the articular pillar between the adjacent facet joints (see Chapter 30H, Fig. 30H.1).
- The shaft of the needle appears as a single dot, as demonstrated in Fig. 30G.2.
  - Needle bevel rotation or "jiggle" can help visualize the needle tip in the out-of-plane confirmation view.
  - The use of magnification can help identify subtle needle motion (as noted in Chapter 4).
- This is not a safety view. Instead, use an in-plane image for safe needle advancement to best visualize the corresponding landmarks.
- Use caution when using the out-of-plane view to reposition the needle.
- The needle appears as a dot on the US image. The dot may represent the tip or any part of the shaft of the needle.

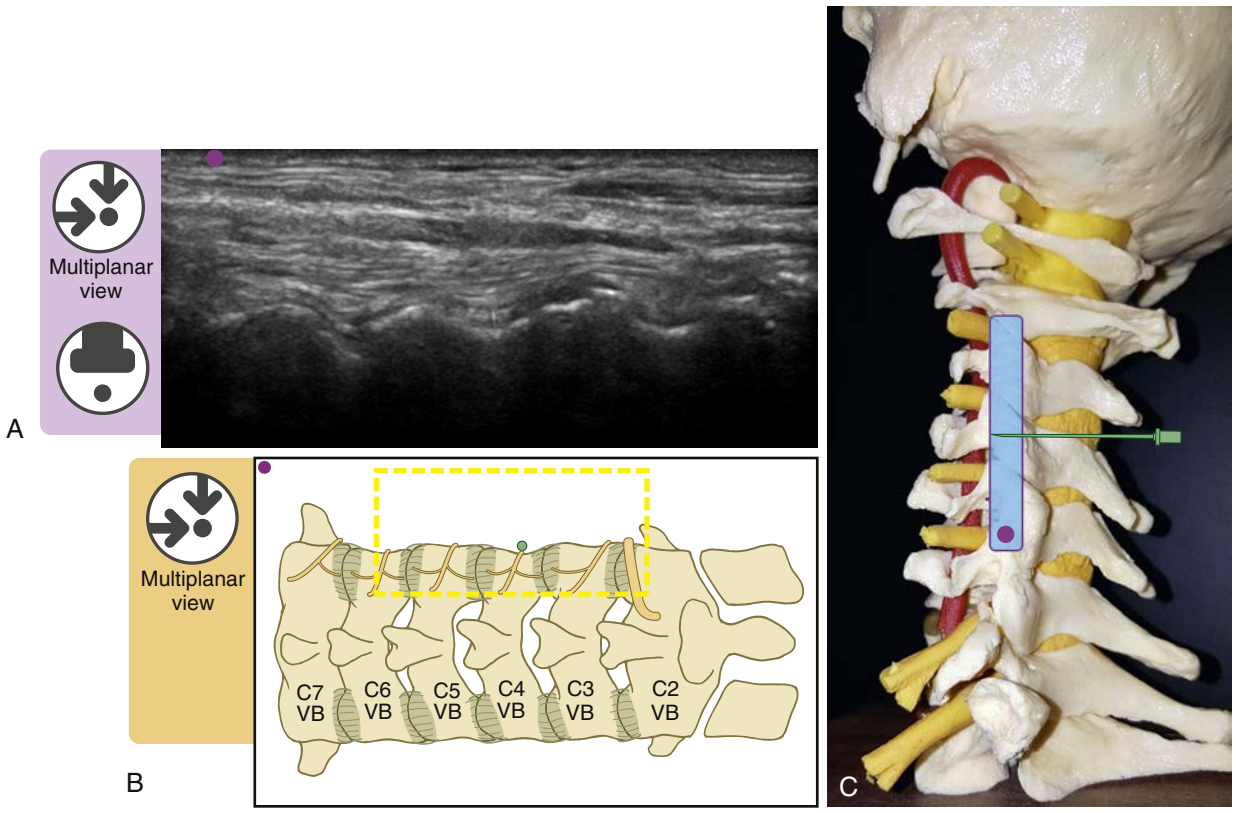

Fig. 30G.2. A, Ultrasound (US) image of out-of-plane needle placement at the targeted medial branch on the articular pillar. **B**, Drawing of relevant structures corresponding to Fig. 30G.2A. Yellow dashed line represents US image borders seen in Fig. 30G.2A. **C,** Proper US transducer placement demonstrating 90-degree rotation from the in-plane view.

Optimal Needle Placement and Images

Please see the optimal fluoroscopic images in Chapter 30F, Figures 30F.8 and 30F.9, Cervical Zygapophysial Joint Nerve (Medial Branch) Radiofrequency Neurotomy and Nerve Injection—Posterior Approach: Fluoroscopic Guidance. Also see the figures and diagrams in Chapter 30H.

Suboptimal Needle Placement and Images (Figs. 30G.3 and 30G.4)

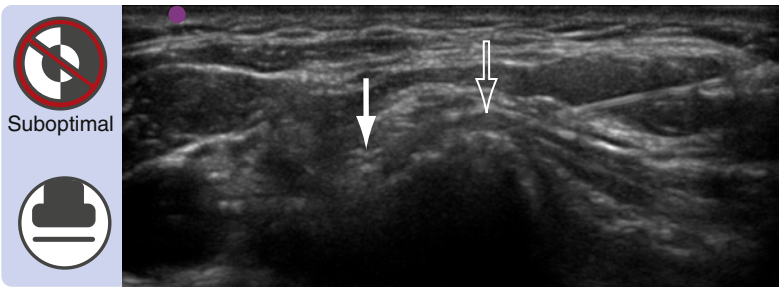

Fig. 30G.3. Suboptimal in-plane view of cervical medial branch block needle placement. The needle tip is in the facet joint (*open arrow*) instead of at the targeted trough (closed arrow) with the medial branch (not shown). The transducer needs to be repositioned cephalad or caudad over the correct target.

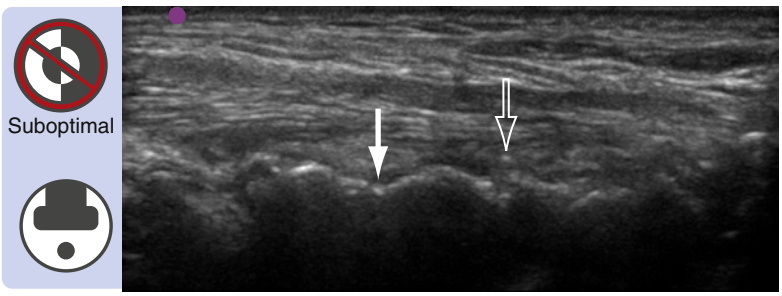

Fig. 30G.4. Suboptimal out-of-plane view of cervical medial branch block needle placement. The needle tip (*open arrow*) is not in the targeted trough with the medial branch (*closed arrow*).

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1. Spinner DA. Spine. In: Spinner DA, Kirschner JS, Herrera JH, eds. *Atlas of Ultrasound Guided Musculoskeletal Injections*. New York: Springer; 2013:123–137.
2. Siegenthaler A, Mlekusch S, Trelle S, Schliessbach J, Curatolo M, Eichenberger U. Accuracy of ultrasound-guided nerve blocks of the cervical zygapophyseal joints. *Anesthesiology*. 2012;117(2):347–352.
3. Lee SH, Kang CH, Lee SH, et al. Ultrasound-guided radiofrequency neurotomy in cervical spine: sonoanatomic study of a new technique in cadavers. *Clin Radiol*. 2008;63(11):1205–1212.

Suggested Readings

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CHAPTER 30H

Cervical Zygapophysial Joint Innervation: Anatomy, Dissections, and Lesion Zone Diagrams

Jeffrey R. Conly, Luis Baez-Cabrera, Isaac Cohen, Brian F. White, and Michael B. Furman

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

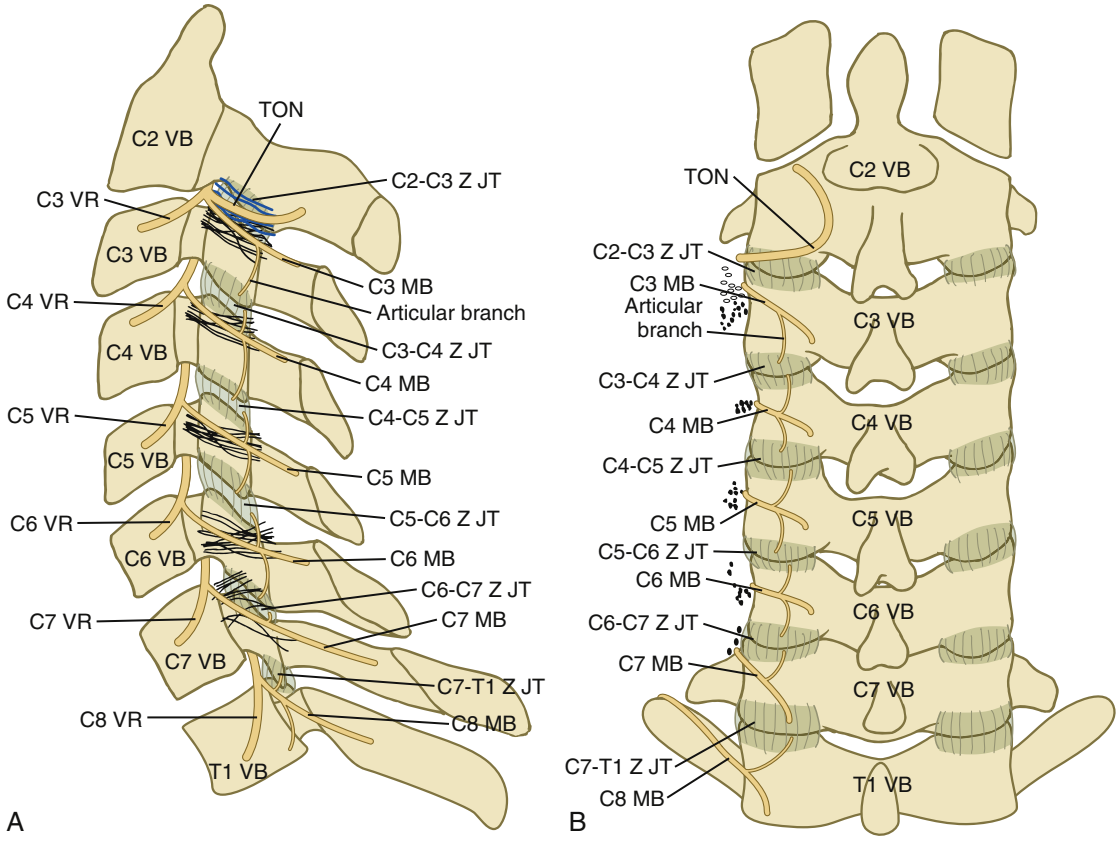

Fig. 30H.1. Illustration of an idealized cervical spine showing the variable course of cervical medial branches relative to bony landmarks, demonstrating the variability noted in consecutive cadaver dissections. **A,** Lateral view. Each line represents the nerve course of one cadaver specimen. The variable courses of the third occipital nerve (TON) (i.e., the C3 superficial medial branch) and the C3-C7 medial branches are shown. Note how the variable courses of the TON (*blue*) and the C3 deep medial branches (*black*) overlap with each other. Also note that the C5 medial branches course along the middle aspect of the C5 articular pillar, but the other medial branches are located progressively higher on their respective articular pillar as the level progresses further away from the C5 level. Note that the C8 medial branch is illustrated but not relevant for blockade in a lateral view. **B,** Anteroposterior view. Each dot represents the cross section of one cadaver specimen's nerve course. The variations in location of the TON are shown as larger open circles, whereas the lower cervical medial branches are shown as smaller solid dots. (TON, C3-C7 figure(s) used and modified with permission from Lord SM, McDonald GJ, Bogduk N. Percutaneous radiofrequency neurotomy of the cervical medial branches: a validated treatment for cervical zygapophysial joint pain. *Neurosurg Q.* 1998;8(4):288-308.)

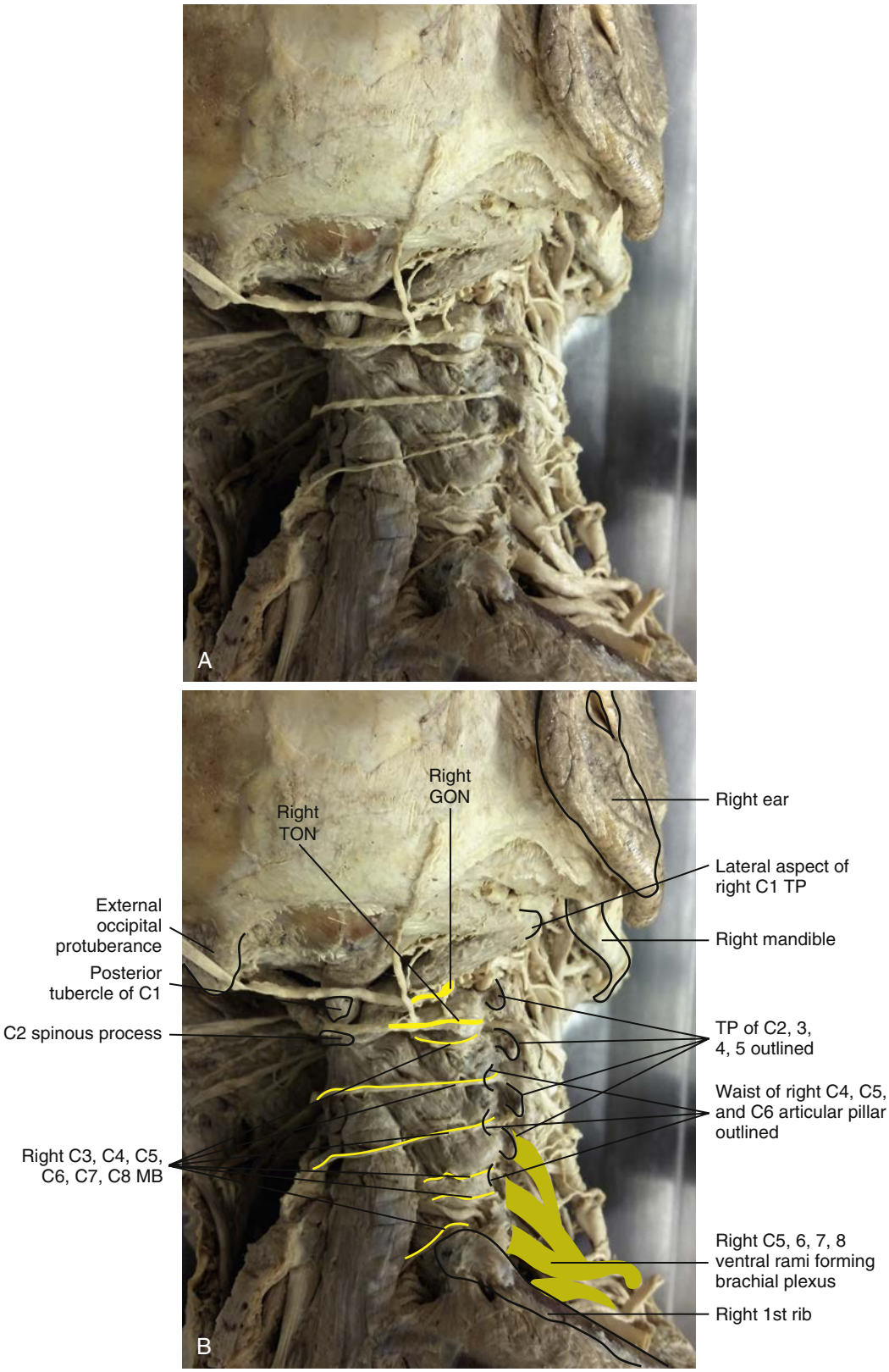
A
B
Right GON
Right TON
Right ear
Lateral aspect of right C1 TP
Right mandible
External occipital protuberance
Posterior tubercle of C1
C2 spinous process
TP of C2, 3, 4, 5 outlined
Waist of right C4, C5, and C6 articular pillar outlined
Right C3, C4, C5, C6, C7, C8 MB
Right C5, 6, 7, 8 ventral rami forming brachial plexus
Right 1st rib

Fig. 30 H.2 A and B. Cadaveric dissection of the cervical spine. Image viewed from near AP position with ~10 degrees of right oblique. **A,** Unlabeled view. Medial branches (MB) are clearly viewed at C3 to C8 levels. Note the relatively larger size of the cervical MB when compared to those in the lumbar spine viewed in the dissection images 15 E.2. The greater occipital nerve (GON) is visible as it emerges inferior to the obliquus capitis inferior muscle, and the third occipital nerve (TON) is visible immediately cephalad to the C3 MB. The posterior tubercle of C1 and the tip of the C2 spinous process are noted in the midline. The C1 to C5 transverse processes (TP) are visible and are located slightly inferior and lateral to the MB of the same level. The location of the lower cervical TP can be approximated by their relation to the visible neurologic structure but are not directly visualized in this view. The right supraclavicular brachial plexus is seen proximal to the level of the trunks and lying above the right first rib. **B,** Labeled view. Black lines highlight salient osseous structures noted above as well as the waist of the articular pillar at the C4, C5, and C6 levels. Bright yellow lines highlight the position of the GON, TON, C3 – C8 MB. Gold structures are the C5 – C8 ventral rami forming the proximal portion of the brachial plexus. Cadaveric specimens and dissection provided courtesy of Professor Frank Willard and the Anatomy Department at the University of New England College of Osteopathic Medicine, Biddeford, ME.

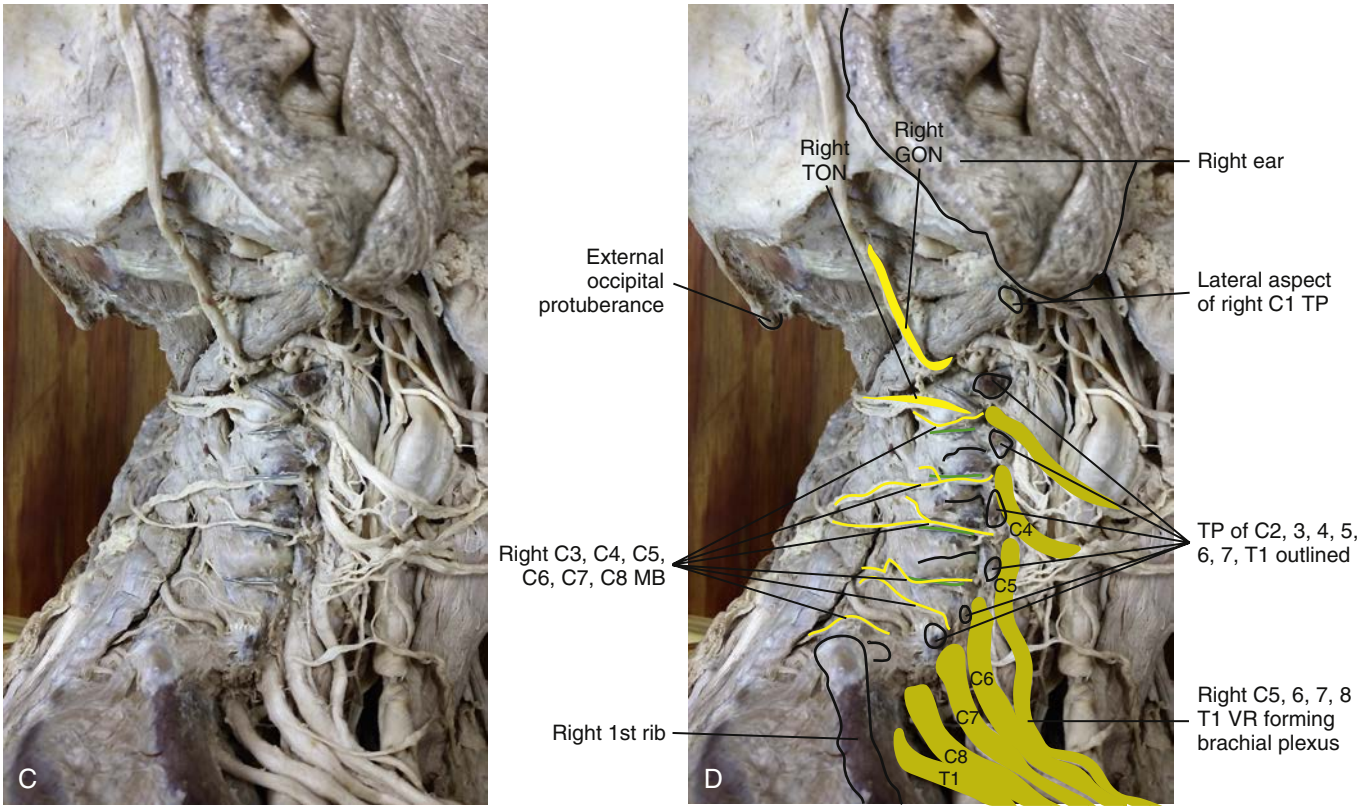

Fig. 30 H.2 C and D cont'd Cadaveric dissection of cervical spine images viewed from lateral position. Wires have been placed in close approximation to the C3, C4, C5, and C6 MB. **C,** Unlabeled view. A wire is also placed near the TON; however, note that the wire placement has migrated to a position superior to the actual anatomic course of the TON additionally, the wire has an exaggerated cephalad angulation relative to the anatomic position of the TON. GON is seen emerging from beneath the obliquus capitis inferior muscle and the lateral aspect of C1 TP is seen directly below the ear. The C3 – T1 level ventral rami (VR) can be seen extending anteriorly with the C5 – T1 levels forming the brachial plexus. The first rib is seen in the lower aspect of the image. **D,** Labeled view. Black lines highlighting osseous structures in the lateral view. TP are prominently visible at the C1 and C2 levels and can also be seen at lower cervical levels; black lined ovals highlight the lateral projection of the C1 – T1 TP. Lateral margin of the facet joints at the C3-C4, C4-C5, and C5-C6 levels are visible highlight with black lines over the joint margin. Lower level cervical facet joints are not directly visible, but their location can be inferred by the position of visualized neurologic structures. Yellow lines demonstrate the C3 – C8 MB and the GON and TON. Green lines highlight the positon of wires placed along the C3, C4, and C5, MB. Gold colored structures are C3 – T1 level ventral rami. Cadaveric specimens and dissection provided courtesy of Professor Frank Willard and the Anatomy Department at the University of New England College of Osteopathic Medicine, Biddeford, ME.

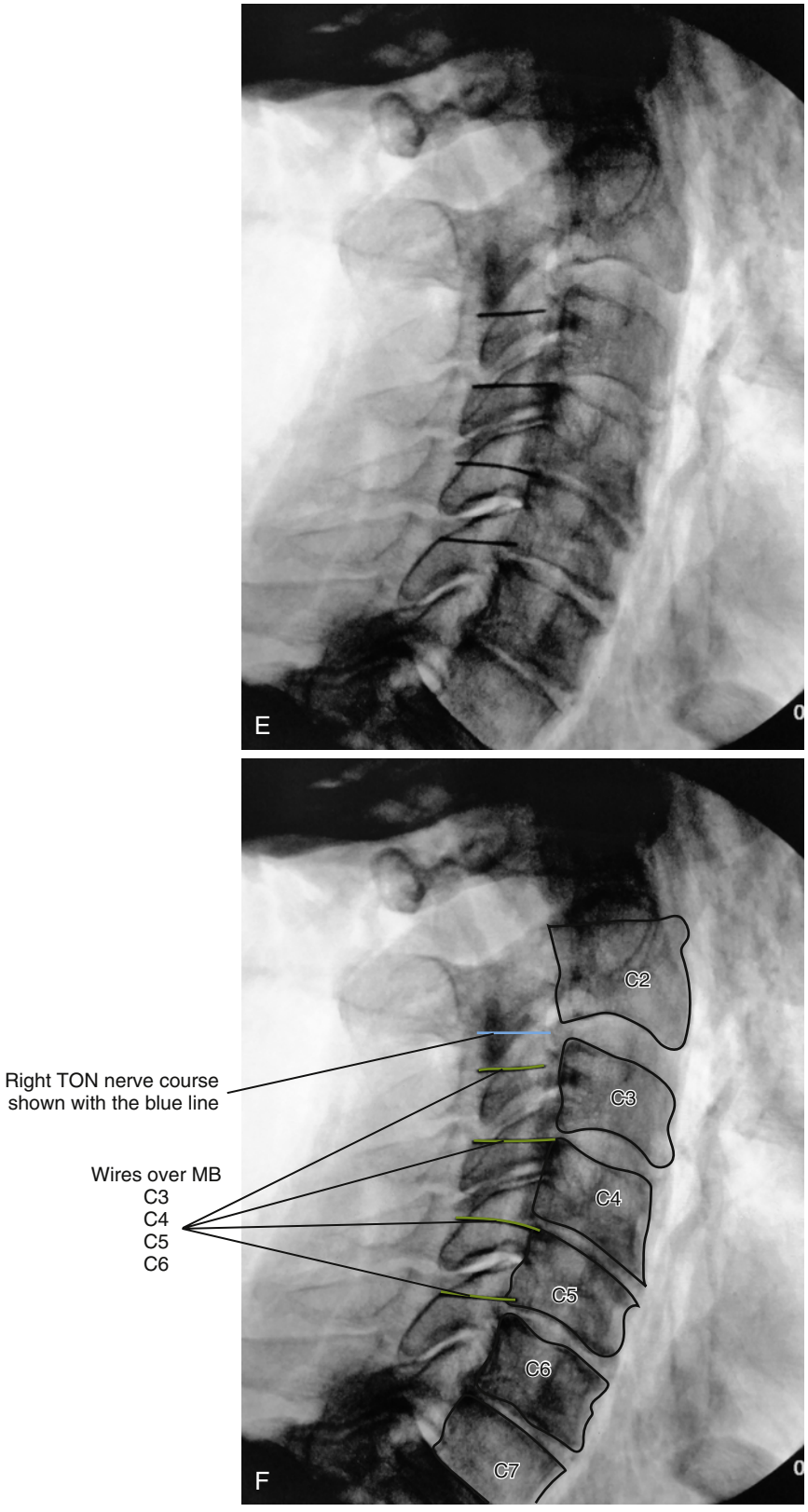

Fig. 30 H.2 E-H cont'd Fluoroscopic images of the cadaveric dissection viewed above in Fig. 30 H.2 A-D. Lateral (**E** and **F**) and AP (**G** and **H**) fluoroscopic views are presented with wire segments placed along the course of the medial branches at the C3 – C6 levels. **E and F**. Lateral views, **E,** unlabeled and, **F,** labeled. This view is a fluoroscopic image of the cadaveric view seen in Fig. 30 H.1. **E** (unlabeled) and **F** (labeled). Black lines outline the vertebral bodies of C2 – C7. Green lines highlight the wires placed along the course of the C3 – C6 MB. No wire is shown along the TON in **E**. A blue line represents the TON course in **F**. Cadaveric specimens and dissection provided courtesy of Professor Frank Willard and the Anatomy Department at the University of New England College of Osteopathic Medicine, Biddeford, ME.

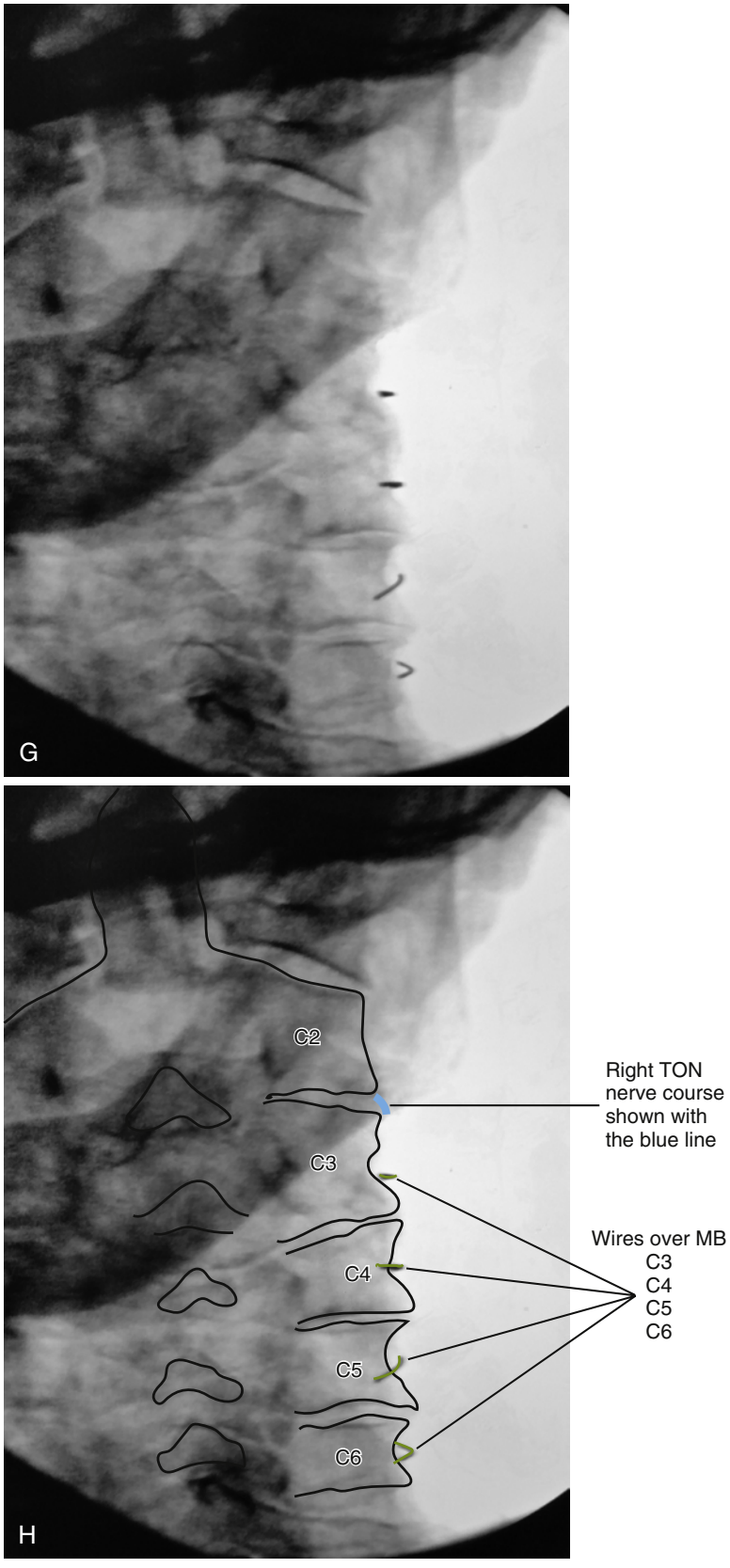

Fig. 30 H.2 G-H cont'd This view is a fluoroscopic image of the cadaveric view seen in Fig. 30 H.1. **G** (unlabeled) and **H** (labeled). Black lines outline the articular pillars of C2 – C6. Green lines highlight the wires placed along the course of the C3 – C6 MB. No wire is shown along the TON in EG. A blue line represents the TON course in **H**. Cadaveric specimens and dissection provided courtesy of Professor Frank Willard and the Anatomy Department at the University of New England College of Osteopathic Medicine, Biddeford, ME.

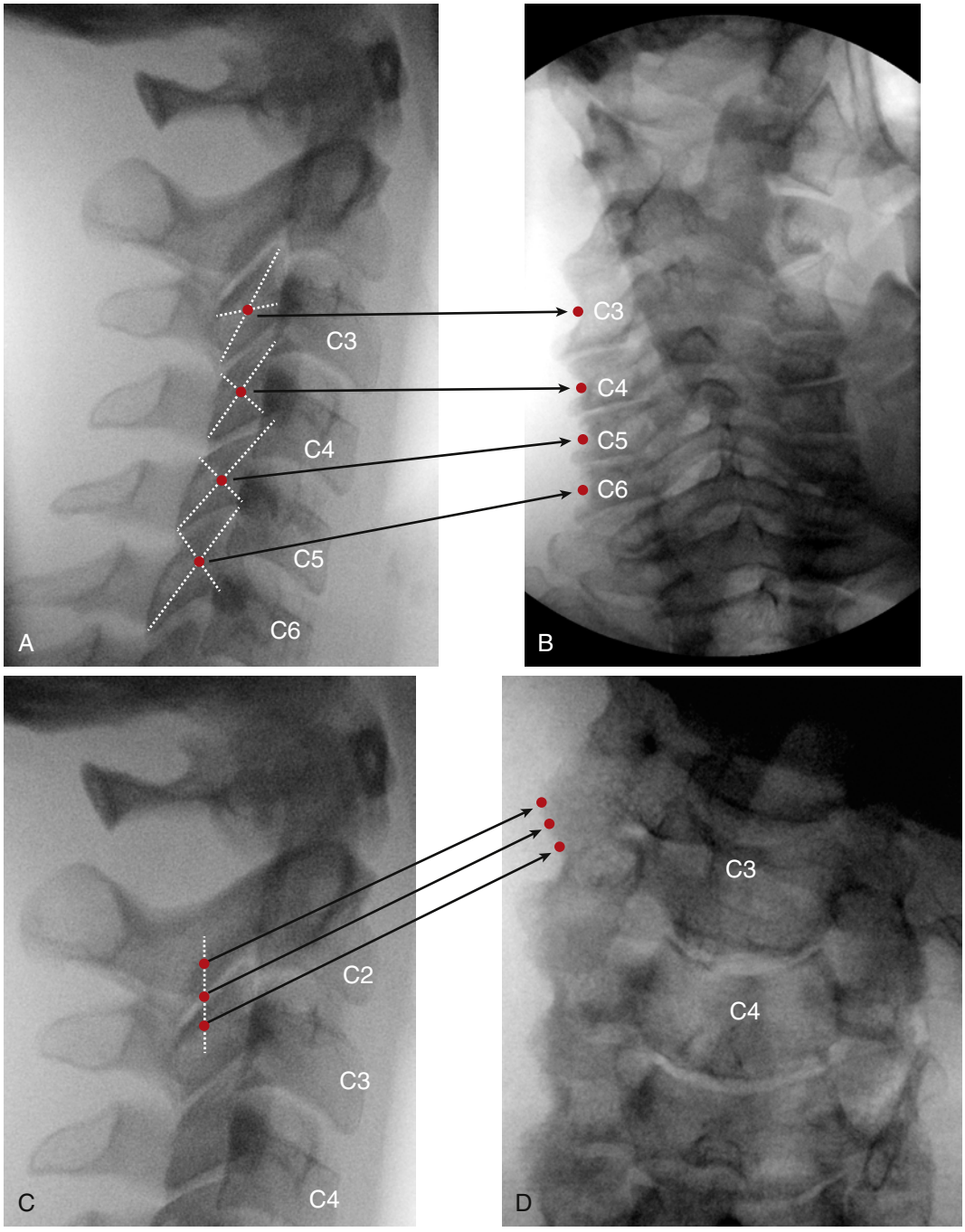

Fig. 30H.3. A-B C3-6 medial branch block. **A,** Lateral and, **B,** AP demonstrate suggested targets for C3 through C6 medial branch blocks. An anatomic validation study by Barnsley[1] demonstrated that blocking a single point for the C3-6 medial branches (centroid of the articular pillar) is sufficient to encompass all the known locations of the C3-6 medial branches. Third occipital nerve and C7 medial branch blocks require different and multiple block points, given the different bony anatomy and greater cephalocaudal variability in location relative to the C3-6 medial branches. **C-D** Third occipital nerve block. **C,** Lateral and, **D,** AP demonstrate suggested targets for the third occipital nerve. Three block points along the vertical bisector of the C2-3 joint are required to encompass all known locations of the third occipital nerve as it winds around the lateral aspect of the C2-3 joint: (1)apex of the C3 SAP, (2)base of C2-3 foramen, and (3) in between the above two points. Cadaveric specimens and dissection provided courtesy of Professor Frank Willard and the Anatomy Department at the University of New England College of Osteopathic Medicine, Biddeford, ME.

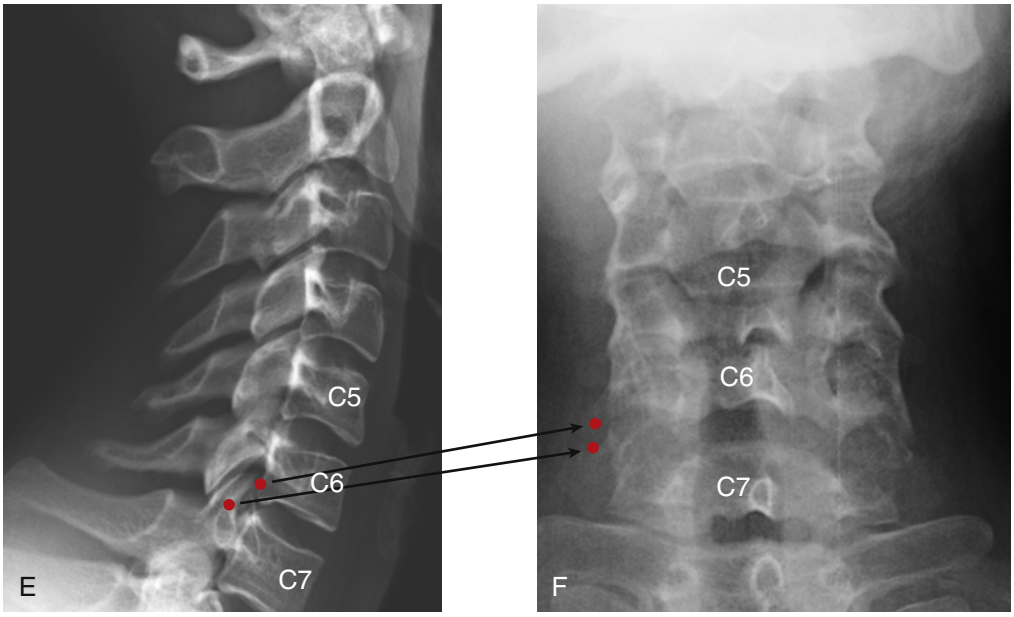

Fig. 30 H.3 E-F cont'd E-F C7 medial branch block. **E,** Lateral and, **F,** AP demonstrate suggested targets for the C7 medial branch. The C7 medial branch crosses either the C7 SAP or proximal aspect of the C7 transverse process; hence two block points are recommended. Cadaveric specimens and dissection provided courtesy of Professor Frank Willard and the Anatomy Department at the University of New England College of Osteopathic Medicine, Biddeford, ME.

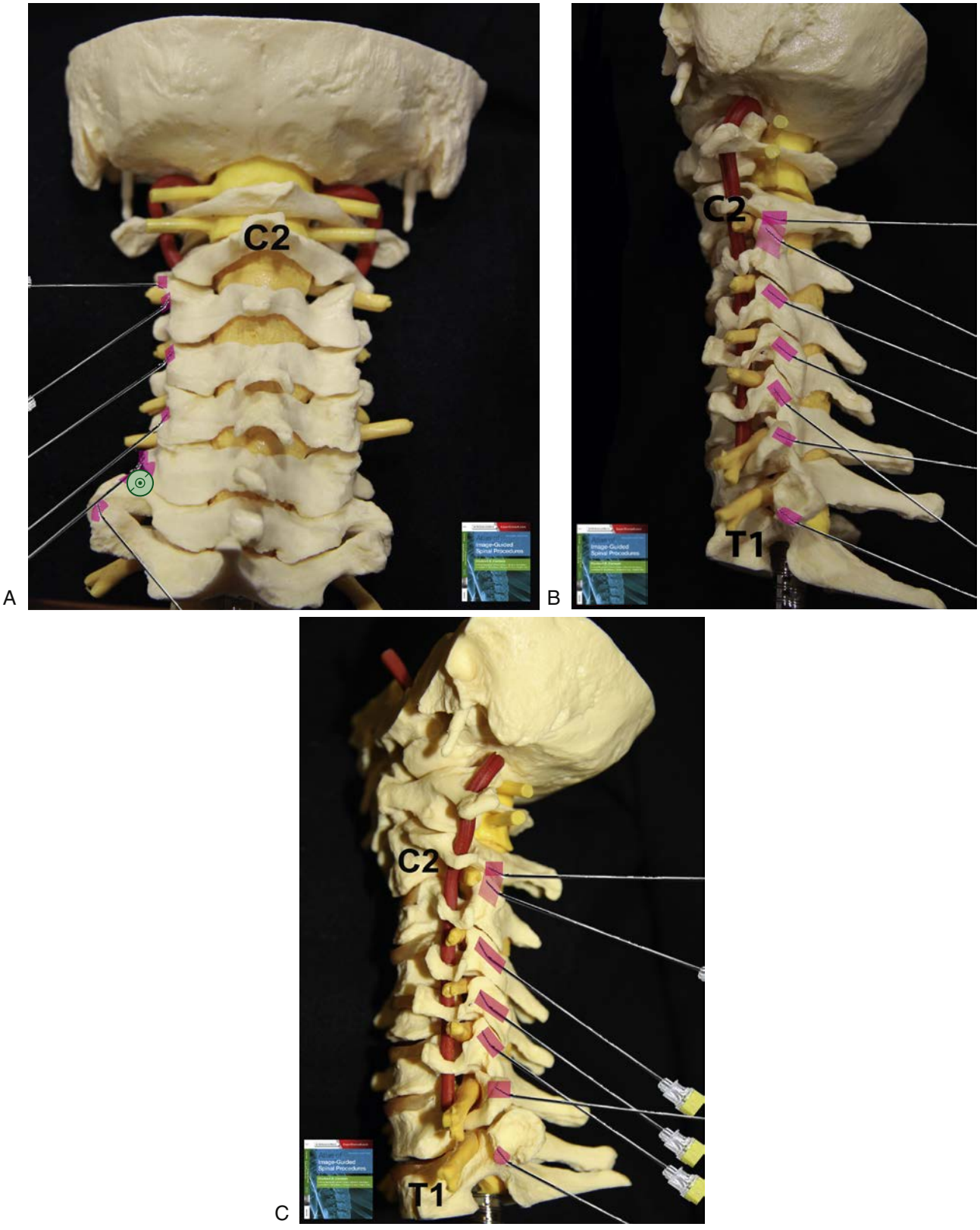

Fig. 30H.4. Illustration and model of an idealized cervical spine with radiofrequency electrode positioning and cervical medial branch (MB) lesion sites for the third occipital nerve through C8 MBs based on the variable course of the cervical MBs relative to bony landmarks. The target "zone" for neurotomy is demonstrated as pink region based on and extrapolated from known MB anatomy demonstrated and referenced in Fig. 30H.1 as well as "zones" described in SIS Guidelines.[2] **A,** Anteroposterior view. **B,** Lateral view. **C,** Oblique view. (For a high-resolution version of these images, go to www.expertconsult.com.)

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2. Bogduk N. Editor. *Practice Guidelines for Spinal Diagnostic and Treatment Procedures (Second Edition).* Hinsdale, IL: International Spine Intervention Society, 2014.

CHAPTER 31

Atlantoaxial Joint Intraarticular Injection

Christopher Bednarek, William A. Rollé Jr., and Michael B. Furman

The atlantoaxial (a0) joints are the paired articulations between the inferior articulating processes of the atlas and the superior articulating processes of the axis. These joints are primarily responsible for the 0 to 45 degrees of lateral rotation in each direction of the cervical spine. These joints can become a source of axial cervical pain in the event of cervical trauma or as a result of degenerative joint disease. In the presence of atlantoaxial joint arthropathy, pain is usually exacerbated by cervical rotation. The distribution of axial cervical pain from atlantoaxial joint arthropathy usually involves the ipsilateral retromastoid, suboccipital, or posteroauricular region.

Atlantoaxial joint injections are indicated for the diagnosis and management of upper cervical pain and headache that emanate from the atlantoaxial joints of the cervical spine. For patients with predominantly unilateral pain, the ipsilateral joint is injected. These joints can be injected with either a lateral or posterior approach. The posterior approach is widely considered to be a safer technique because fewer vital vascular and neural structures are encountered between the skin and joint line when using this trajectory.

In this chapter, a posterior approach is described for the injection of the lateral portion of the atlantoaxial joints. With this approach, the joint is accessed by using a trajectory view and advanced with the use of multiplanar imaging, with an emphasis on safety by using the lateral view to confirm the depth. Because the lateral view is used to assess the depth, one need not “step off” the inferior or superior articulation of the joint before penetrating the joint capsule, as is often recommended. With this approach, the trajectory view is an anteroposterior view with a slight caudad tilt (i.e., a pillar view); this also serves as one of the multiplanar views.

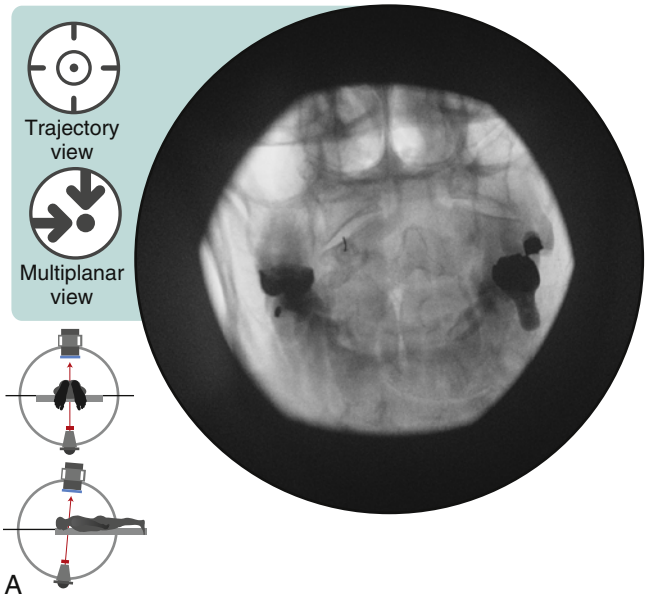
It is crucial to precisely target the lateral one third of the atlantoaxial (aa) joint because straying too far medially or laterally can have devastating consequences.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

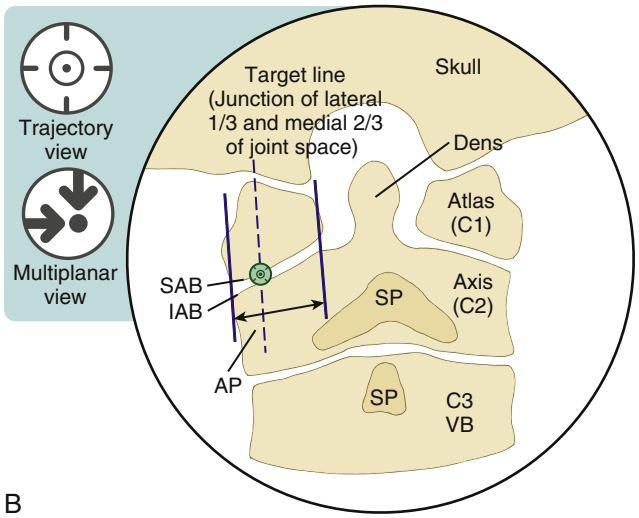
Trajectory View (Fig. 31.1)

- **Place the patient in the prone position** with the neck slightly flexed and the head supported.
- **Confirm the level** (with the anteroposterior view).
- **Tilt the fluoroscope's image intensifier slightly cephalad or caudad** to maximally view the targeted joint space silhouette and facilitate easier entry between the two joint articulations.
- Optimize the superior articular border (sab) and inferior articular border (iab) to the appropriate orientation.
- Stay at the junction of the lateral one third and the medial two thirds of the joint space.

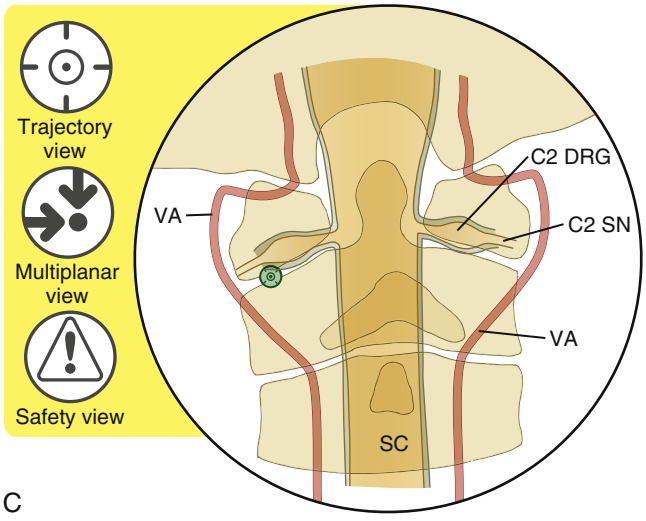
The Trajectory View (Anteroposterior) Is Also a Multiplanar View



A



B



C

Trajectory View Safety Considerations

- Stay at the junction of the lateral one third and medial two thirds of the joint space.
- Avoid penetrating the vertebral artery by not going beyond the lateral border of the joint space.
- Avoid the C2 spinal nerve, C2 dorsal root ganglion, and spinal cord by not straying too far medial.

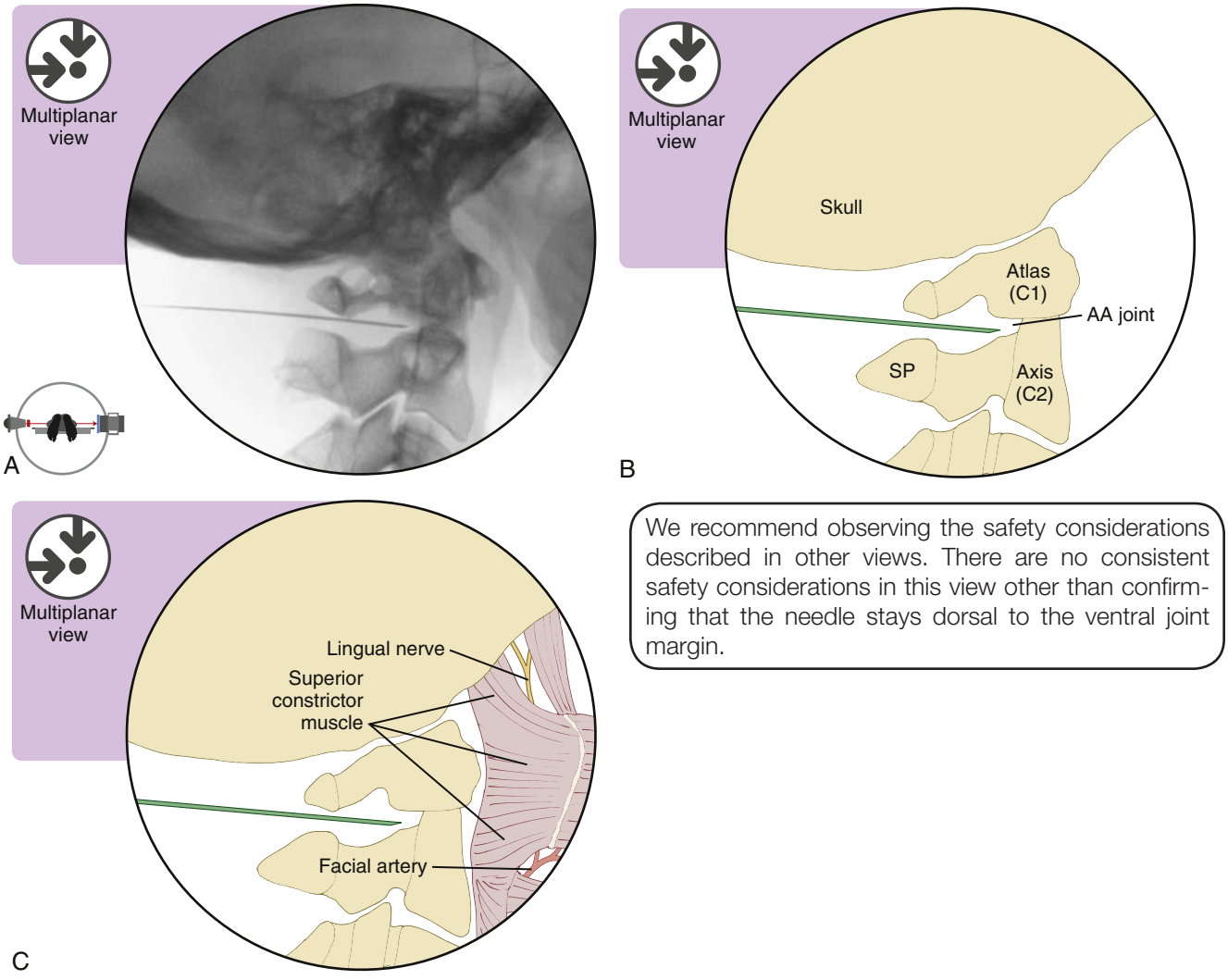
Fig. 31.1. A, Fluoroscopic image of the trajectory view with the needle in position between the superior articular border (SAB) and inferior articular border (IAB). **B,** Radiopaque structures, anteroposterior (AP) trajectory view. (Dentition not drawn in.) **C,** Radiolucent structures, AP trajectory view. Figure 32.6 demonstrates an angiogram to visualize the course of the vertebral artery (VA) relative to the atlantoaxial (aa) and atlantooccipital (ao) joints and other relevant structures.

Optimal Needle Position in Multiplanar Imaging

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 31.2)

Notes on Optimal Needle Positioning

- The needle tip should remain within the joint silhouette in multiple planes.
- The tip of the needle should be seen entering the posterior most aspect of the joint space. The needle should be advanced minimally to avoid ventral joint penetration.



We recommend observing the safety considerations described in other views. There are no consistent safety considerations in this view other than confirming that the needle stays dorsal to the ventral joint margin.

Fig. 31.2. A, Fluoroscopic lateral view with the ideal needle position. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view. The Fig. 31.4 arthrogram demonstrates the joint's extent in lateral view.

Optimal Images (Figs. 31.3 to 31.5)

Ideal contrast flow should appear as a horizontal radiopacity across the width of the joint space, joint capsule, or both.

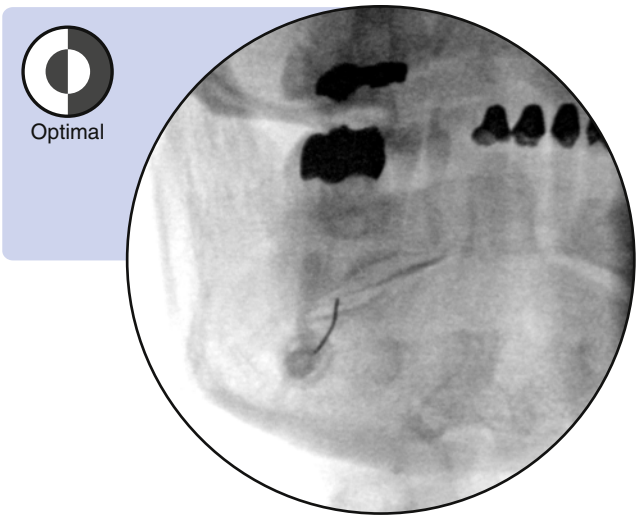


Fig. 31.3. Anteroposterior fluoroscopic image of a left atlantoaxial joint injection with 0.5 cc of contrast medium.

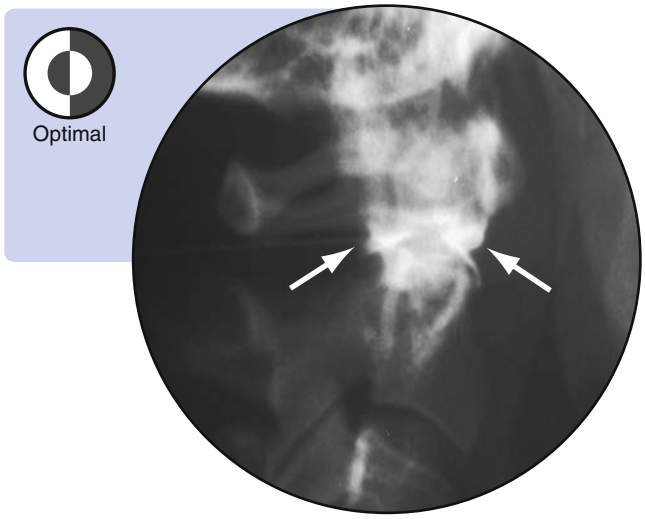


Fig. 31.4. Lateral fluoroscopic image of an atlantoaxial joint injection with 0.5 cc of contrast medium revealing the biconvex shape of the joint (white arrows).

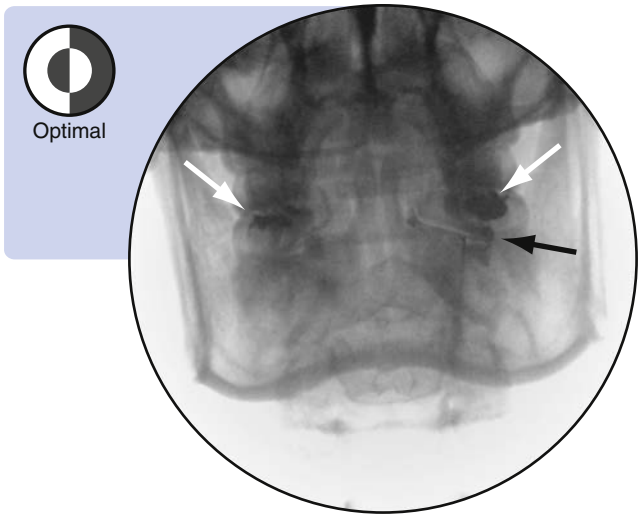


Fig. 31.5. Anteroposterior fluoroscopic image of a right atlantoaxial joint injection with 0.5 cc of contrast medium (black arrow). Contrast is seen flowing within the lateral aspect of the joint space and also extending to the medial and lateral aspects of the joint capsule. Contrast should not be confused with dental work (white arrows).

Suboptimal Images (Fig. 31.6)

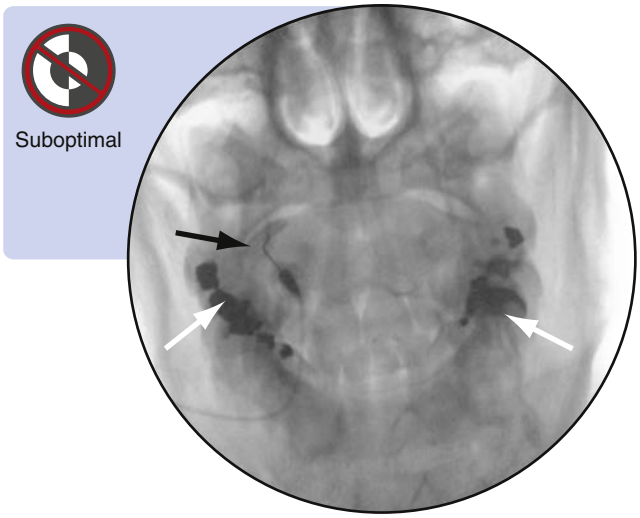


Fig. 31.6. This image represents a suboptimal left atlantoaxial (AA) joint injection that is extraarticular with 0.5 cc of contrast medium (black arrow). The contrast is not in the joint space nor is there lateral or medial capsular filling. Contrast should not be confused with dental work (white arrows).

References

1. Gilchrest RV. Developmental and functional anatomy of the cervical spine. In: Slipman CW, Derby R, Simeone FA, Mayer G, eds. *Interventional Spine: An Algorithmic Approach*. Philadelphia, PA: Elsevier; 2008:519.
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5. Pauza K, Dreyfuss P. Atlanto-occipital and atlantoaxial joint injections. In: Lennard T, ed. *Pain Procedures in Clinical Practice*. 2nd ed. Philadelphia, PA: Hanley & Belfus; 2000:309–320.
6. Bogduk N, ed. *Practice Guidelines for Spinal Diagnostic and Treatment Procedures, Lateral Atlanto-Axial Joint Access*. 2nd ed. San Francisco, CA: International Spine Intervention Society; 2013:35–61.

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CHAPTER 32

Atlantooccipital Joint Intraarticular Injection

Tejas N. Parikh, Hwei (Willie) Lin, and Michael B. Furman

The atlantooccipital (AO) joints uniquely connect the cervical spine (C1, the atlas) to the occiput base. AO joints are condyloid joints. Unlike the lower cervical segments, AO joints lack corresponding cervical discs and uncinate processes. In addition, AO joints lie anterolateral to the spinal cord (SC; rather than posterolateral), and they align with the uncinate processes of the lower cervical bodies. AO joints are very mobile joints with primary ligamentous stabilization, and they are considered to be synovial joints with capsules. The joints facilitate occipital flexion and extension of the atlas (C1).

Patients with AO joint pain often complain of unilateral suboccipital pain that can refer to the occipital and temporal regions but does not include the vertex. This pain can occur after flexion and extension injuries.

Injection into the AO joint can be a challenging endeavor given the proximity of nearby vital neurovascular structures. Familiarity with the regional anatomy will minimize the adverse risks of potentially catastrophic consequences.

The ipsilateral oblique trajectory view and multiplanar imaging allow for safe needle placement into the AO joint, avoiding the vital neurovascular structures. It is crucial to precisely target the lateral one-third of the AO joint because straying too far medially, laterally, or inferiorly can have devastating consequences.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 32.1)

Place the patient in a prone position with the neck slightly flexed and the head supported.

Confirm the level (with the anteroposterior view).

Oblique the fluoroscope 25 to 30 degrees ipsilaterally (to the left, in this case).

Tilt the fluoroscope in a caudad direction to optimally make a direct path to the AO joint (clearing the occipital brim) and to visualize the AO joint as a sharp line so that it is unobstructed by the occipital brim.

The target is the posterior aspect of the joint (because the patient is prone); however, the anterior joint line is what is visualized; it is 1 to 2 mm inferior to the posterior portion.

- Therefore, your target should be just slightly (i.e., 1–2 mm) superior to the visualized anterior joint line while clearing the occiput.

This oblique image is the trajectory view, and the needle is placed parallel to the fluoroscopic beam.

Notes on Positioning in the Trajectory View

- Clear the occipital brim.
- Line up and visualize the AO joint as a sharp line.
- The anterior joint line is what is visualized; it is 1 to 2 mm inferior to the posterior portion.

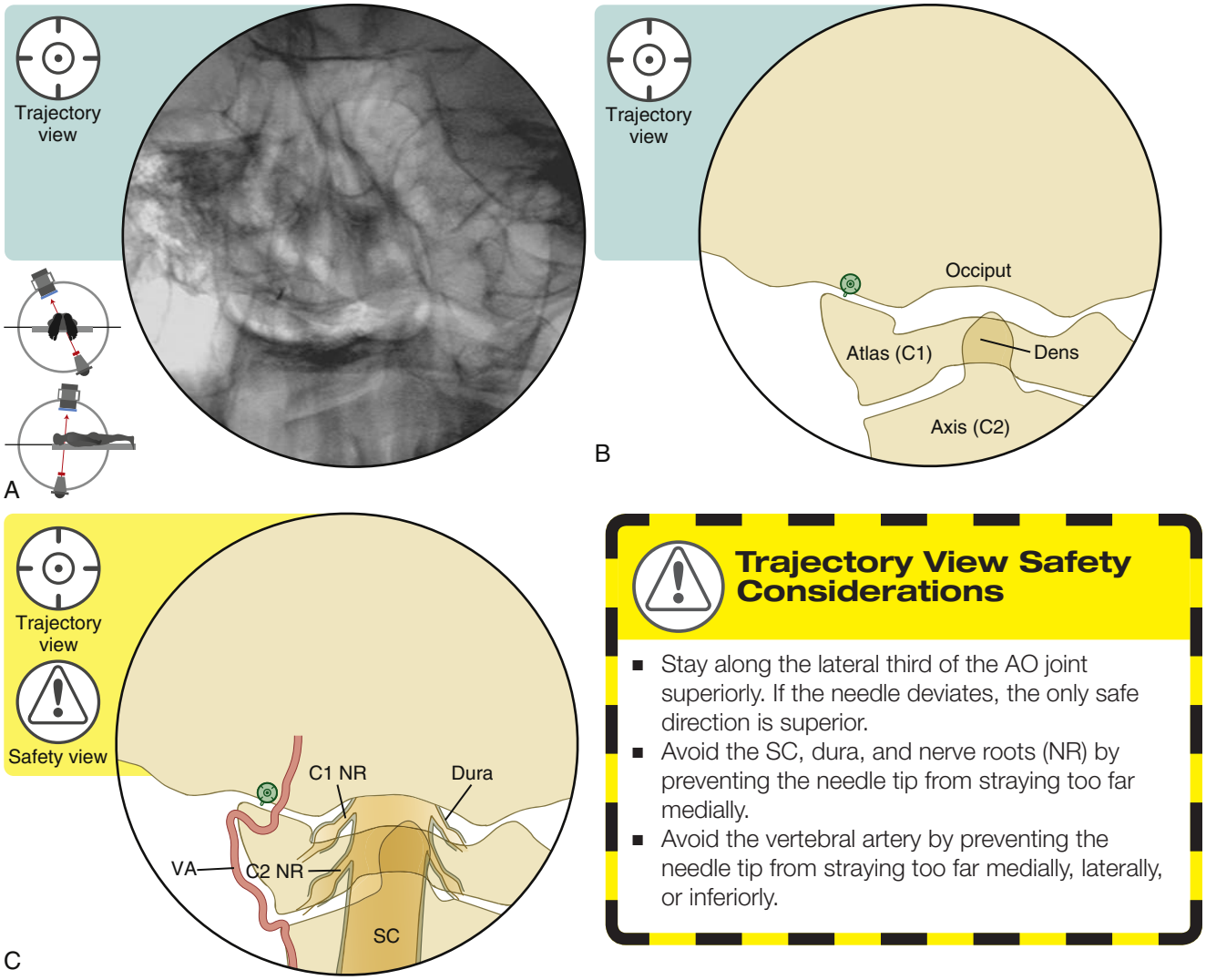

Trajectory view
A
Trajectory view
Occiput
Atlas (C1)
Dens
Axis (C2)
B
Trajectory view
Safety view
C1 NR
Dura
VA
C2 NR
SC
C
Trajectory View Safety Considerations
Stay along the lateral third of the AO joint superiorly. If the needle deviates, the only safe direction is superior.
Avoid the SC, dura, and nerve roots (NR) by preventing the needle tip from straying too far medially.
Avoid the vertebral artery by preventing the needle tip from straying too far medially, laterally, or inferiorly.

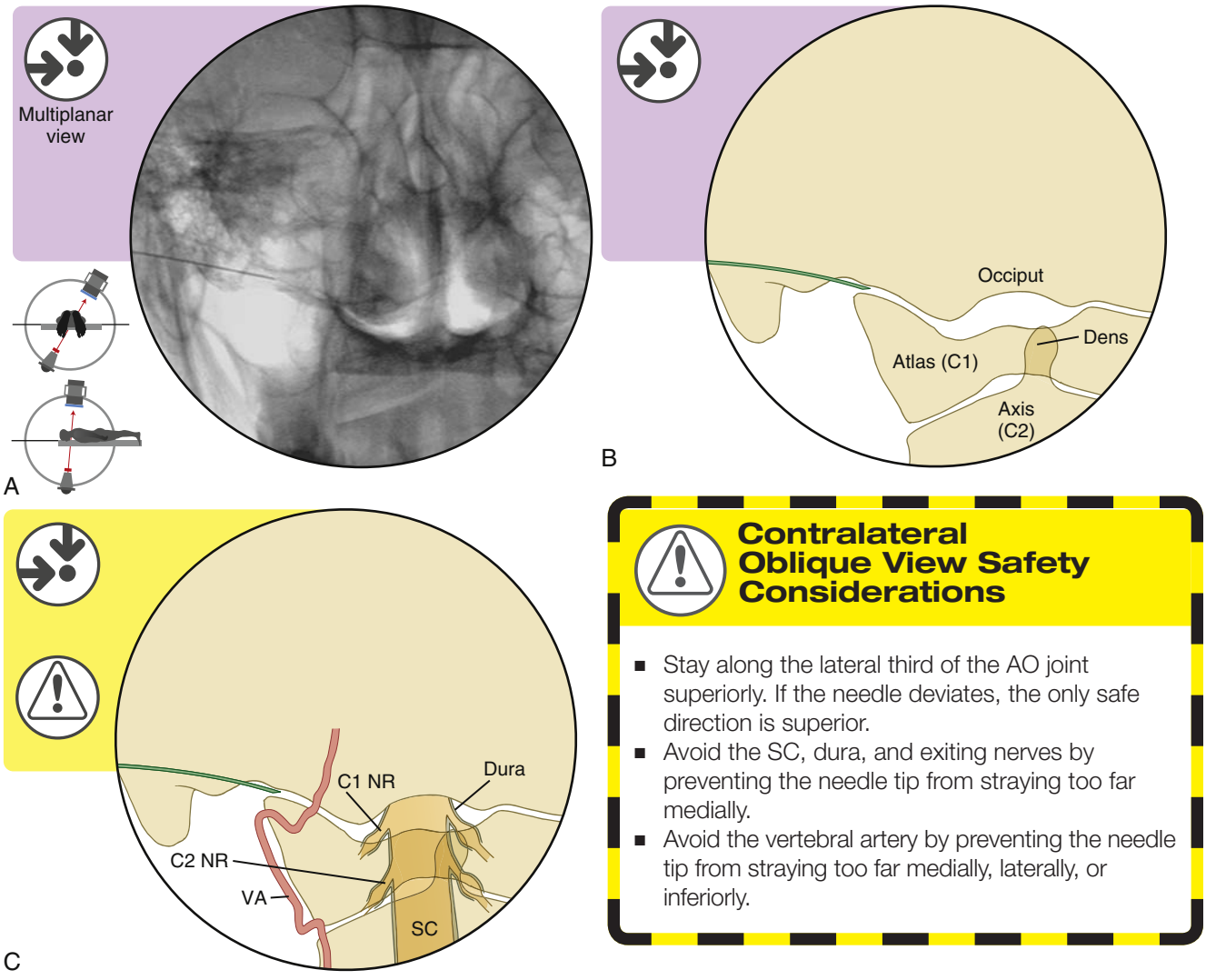
Fig. 32.1. A, Fluoroscopic image of a trajectory (i.e., ipsilateral oblique) view with the needle in position in the left atlantooccipital (AO) joint. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view. Notice that the needle is placed in the lateral one-third of the AO joint.

Optimal Needle Position in Multiplanar Imaging

The multiplanar views that are used are the contralateral oblique, lateral, and anteroposterior.

OPTIMAL NEEDLE POSITIONING IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 32.2)

- As the needle tip approaches the AO joint, rotate the C-arm approximately 25 to 30 degrees to obtain a contralateral oblique view.
- Confirm correct needle placement or guide the needle into the joint (Fig 32.2A) by assessing the superior and inferior orientation of the needle and the ventral depth.
- Alternate between the ipsilateral oblique (see Fig. 32.1) and contralateral oblique (see Fig. 32.2) views to obtain the optimal needle placement.



Contralateral Oblique View Safety Considerations

- Stay along the lateral third of the AO joint superiorly. If the needle deviates, the only safe direction is superior.
- Avoid the SC, dura, and exiting nerves by preventing the needle tip from straying too far medially.
- Avoid the vertebral artery by preventing the needle tip from straying too far medially, laterally, or inferiorly.

Fig. 32.2. A, Fluoroscopic image of a contralateral oblique view with the needle tip in position in the left atlantooccipital joint. **B,** Radiopaque structures, contralateral oblique view. **C,** Radiolucent structures, contralateral oblique view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 32.3)

- The oblique and contralateral oblique views are often the only views that are necessary to obtain optimal needle placement.
- However, we recommend a lateral view to provide information about the anterior and posterior needle tip depth and confirm the intraarticular placement.
- As the needle tip approaches the AO joint, rotate the C-arm approximately 25 to 30 degrees to obtain a contralateral oblique view.
- The C-arm should be oriented to obtain a "true" lateral view (see Chapter 3). We recommend observing the safety considerations described in other views. There are no consistent safety considerations in this view.

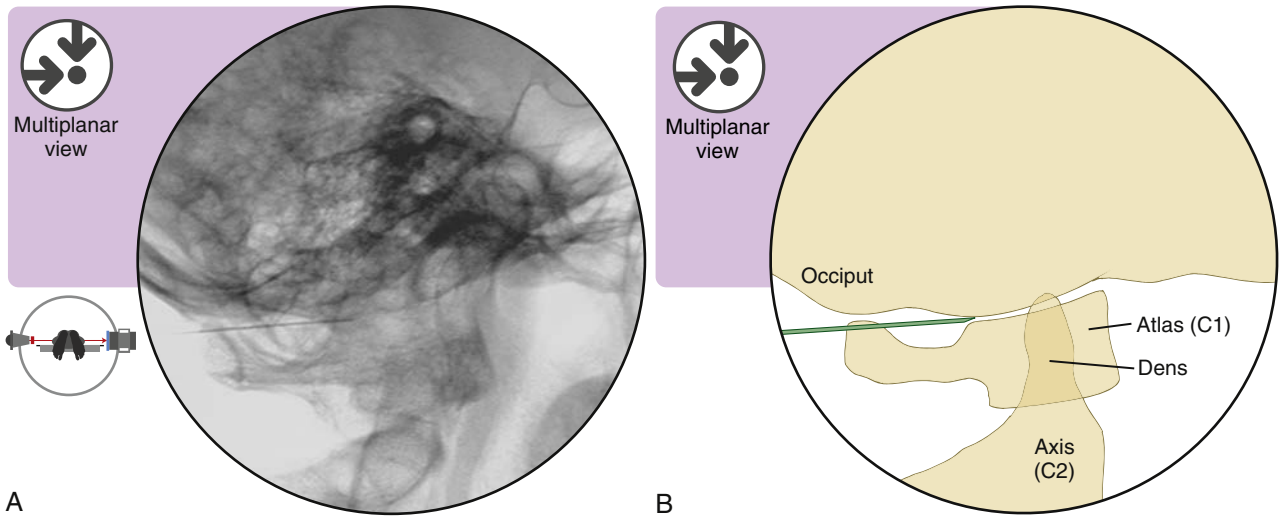


Fig. 32.3. A, Fluoroscopic image of a lateral view with the needle in position in the left atlantooccipital joint. **B,** Radiopaque structures, lateral view.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 32.4)

- The oblique and contralateral oblique views are often the only views that are necessary to obtain optimal needle placement.
- However, we recommend an anteroposterior view to help visualize the needle and advance to the target between the superior and lateral aspects of the AO joint.
- The anteroposterior view also provides orientation for those who are not familiar with the ipsilateral and contralateral oblique views.

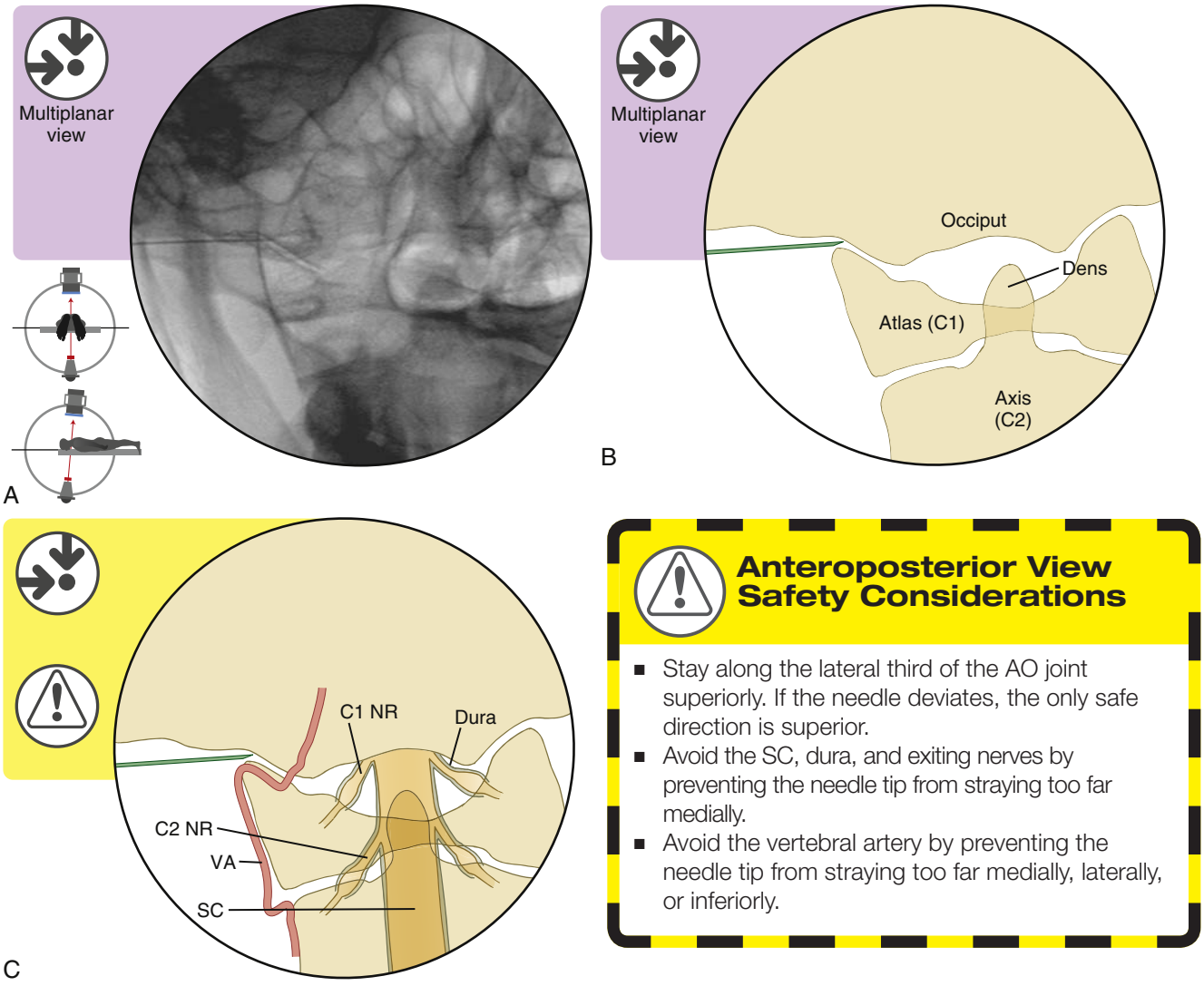
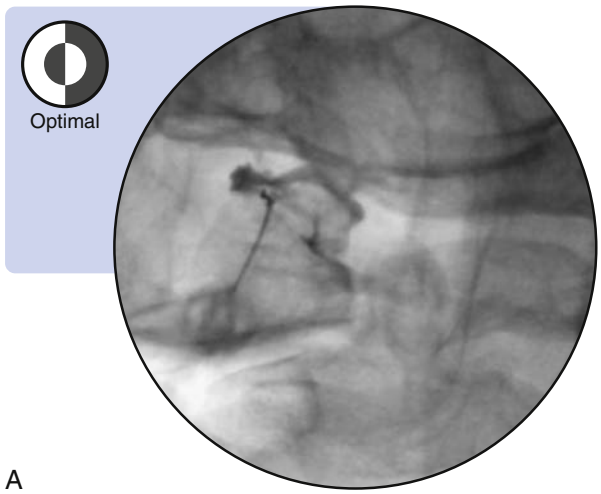

Multiplanar view
A
Multiplanar view
Occiput
Dens
Atlas (C1)
Axis (C2)
B
C1 NR
Dura
C2 NR
VA
SC
C
Anteroposterior View Safety Considerations
Stay along the lateral third of the AO joint superiorly. If the needle deviates, the only safe direction is superior.
Avoid the SC, dura, and exiting nerves by preventing the needle tip from straying too far medially.
Avoid the vertebral artery by preventing the needle tip from straying too far medially, laterally, or inferiorly.

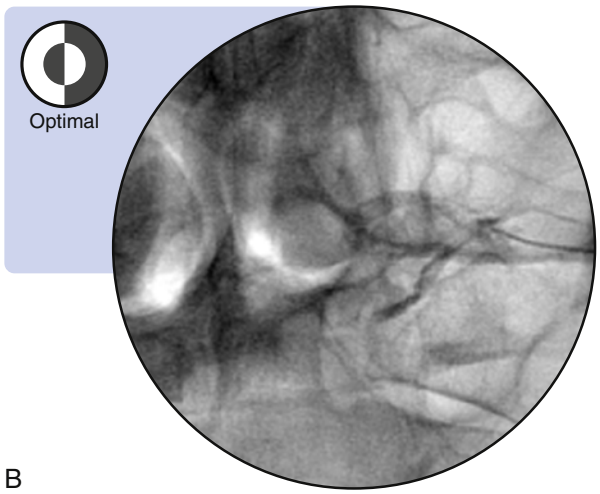
Fig. 32.4. A, Fluoroscopic image of an anteroposterior view with the needle tip in position in the atlantooccipital joint. **B,** Radiopaque structures, anteroposterior view. **C,** Radiolucent structures, anteroposterior view.

Optimal Image (Figs. 32.5 and 32.6)

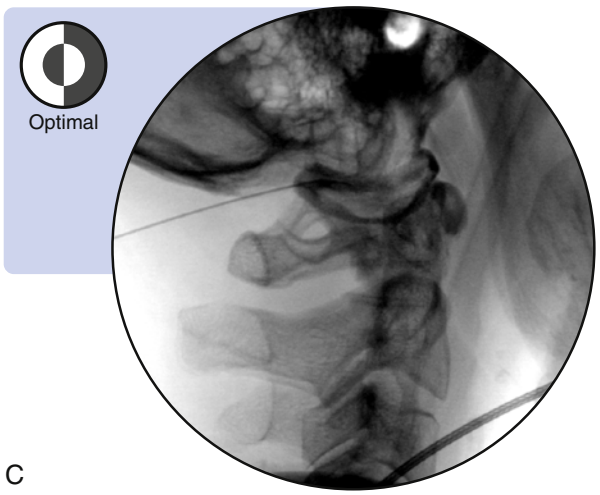
- Optimal flow should be intraarticular and may extend to the inferior and/or superior joint recesses.
- Less than 0.5 ml of contrast medium should be injected into this small joint to allow for additional injectate.



A



B



C

Fig. 32.5. A, Ipsilateral oblique fluoroscopic image of a left atlantooccipital (AO) joint injection. Note the bean-like outline of the AO joint. **B,** Contralateral oblique fluoroscopic image of a left AO joint injection. **C,** Lateral fluoroscopic image of a left AO joint injection. Again, note the bean-shaped outline of the AO joint. Courtesy of Dr. Paul Dreyfuss.

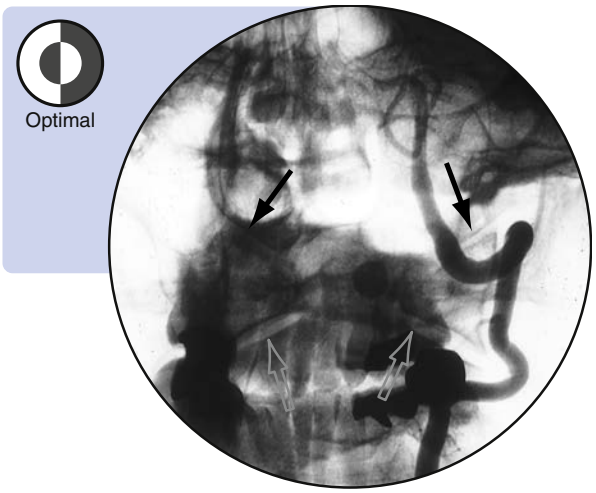


Fig. 32.6. Approximately 20 degrees ipsilateral oblique view of a right vertebral artery (VA) angiogram. Notice the course of VA in relation to the atlantooccipital (AO) and atlantoaxial (AA) joints and other relevant structures. The closed arrow indicates the entry point for the AO joint injection. The open arrows indicate the entry point for the AA joints. Courtesy of Dr. Paul Dreyfuss.

Suboptimal Image

- Suboptimal flow will show an amorphous pattern extending outside of the joint margins.

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CHAPTER 33

Greater Occipital Nerve Steroid Injection—In-Plane Approach

Luis Baez-Cabrera, Paul S. Lin, and Michael B. Furman

INTRODUCTION

The greater occipital nerve (GON) is the main sensory nerve to the occipital area and has been associated with various pain syndromes such as occipital neuralgia, cervicogenic headaches, and migraines. GON derives most of its fibers from the C2 dorsal root, and blocks of this peripheral nerve can provide substantial pain relief.

This chapter describes an in-plane ultrasound-guided technique.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique

- Patient in a prone, side-lying, or seated position with the head slightly flexed.
- Move ultrasound transducer ipsilaterally over GON. Interventionist is contralateral and in line with the transducer and ultrasound screen on the opposite side (see Figure 33.1A).
- Using a high-frequency linear array transducer, localize the bifid spinous process of C2. C1 does not have a bifid spinous process.
- Slide laterally toward the ipsilateral C2 lamina.
- Rotate the lateral part of the transducer cephalad until the transverse process of C1 is visualized (around 20–30 degrees). At this point, you should be able to visualize the relevant muscular tissue planes and GON (Figs. 33.1B and C).
- Insert the needle in-plane from medial to lateral and advance until the needle tip is close to the nerve.

Fig. 33.1. A, Setup for in-plane GON injection with US transducer in short axis to the nerve. The interventionalist and transducer are in line with the ultrasound unit.

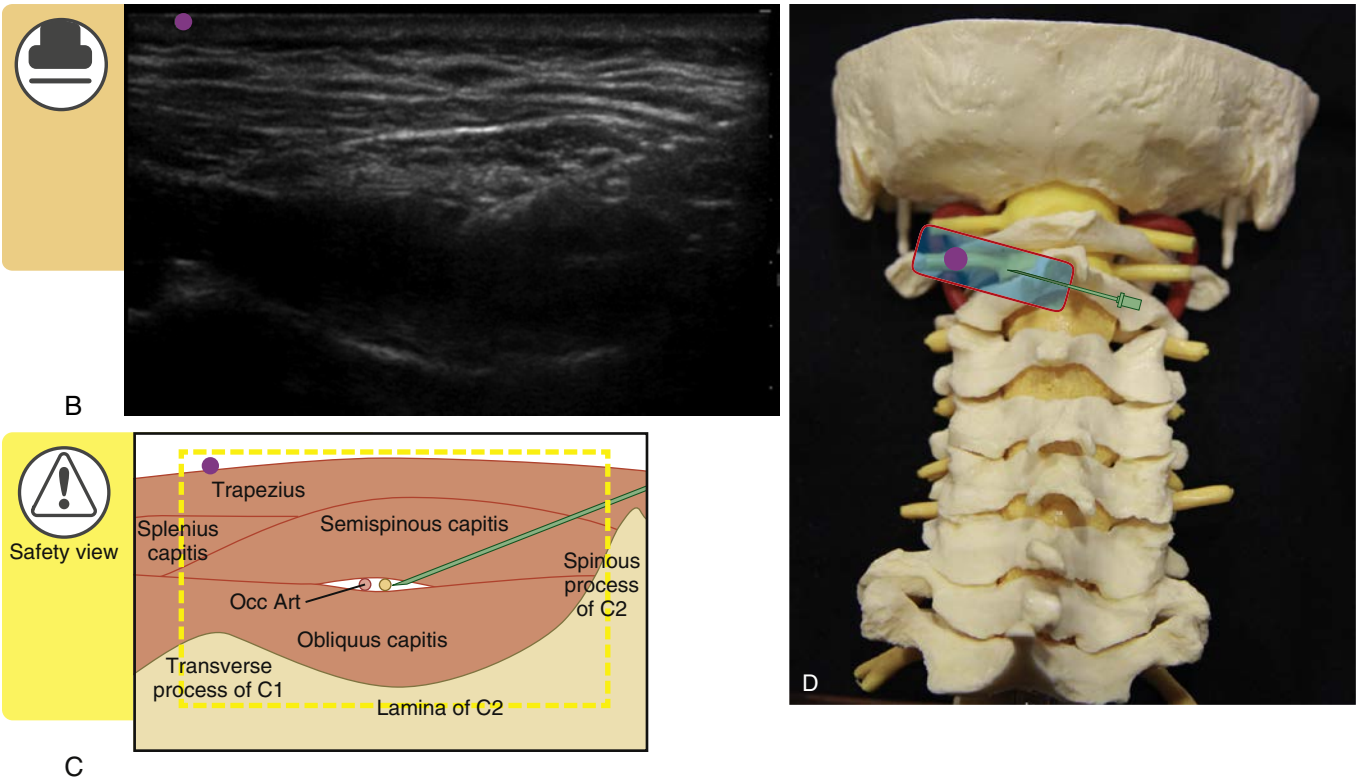

Fig. 33.1, Cont'd B, Ultrasound (US) image of needle placement above the greater occipital nerve (GON) in short axis. **C,** Drawing of relevant anatomic structures. Dashed yellow line demonstrates the region visualized by the US image in B (OccArt, occipital artery). **D,** Skeleton with transducer.

In-Plane Technique Safety Considerations

- Color or power Doppler may help identify the occipital artery, which is in close proximity to GON (see Figure 33.1B). Avoid a vascular injection.

VI

We typically do not perform an out-of-plane, multiplanar confirmation for this procedure.

Optimal Image (Fig. 33.2)

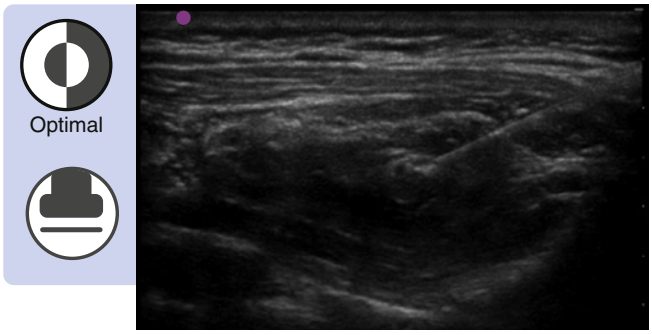

Fig. 33.2. Optimal needle placement with 3 ml of injectate.

CHAPTER 34

Shoulder Region Injections

Primary shoulder pathology can often manifest similarly to cervical radiculopathy or brachial plexopathy. It is important to consider the glenohumeral (GH) joint, subacromial–subdeltoid bursa (SASDB), and acromioclavicular joint (ACJ) as potential sources of pain in patients presenting with symptoms in the neck and shoulder regions.

Both the GH and AC joints are diarthrodial joints and are subject to osteoarthritis, rheumatoid arthritis, trauma, and other synovial joint pathologic conditions. The SASDB, separating the acromion from the supraspinatus tendon, can be a target for intervention in patients suffering from rotator cuff tendinopathy and impingement syndrome.

Although history, physical exam, and imaging can help the interventionalist distinguish cervical pathology from shoulder-generated pain, diagnostic and therapeutic injections can be more definitive. Patients presenting with point tenderness, crepitation, and pain with shoulder forward flexion and active adduction, i.e., cross-arm test, may have ACJ pathology. Pain, range of motion deficits in all planes, and crepitus can indicate evidence of GH intraarticular compromise. Impingement signs and pain with abduction and external rotation are more indicative of subacromial–subdeltoid bursitis. These findings, however, can overlap, making it difficult to isolate the source of pain, and thereby effectively treat the patient.

In this chapter, we will review both fluoroscopy- and ultrasound-guided techniques (Fig. 34.1) to access these shoulder region structures. Use of ultrasound saves the patient from radiation exposure and allows the interventionalist to safely inject the intended structure while avoiding other unintended, potentially vital, structures.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

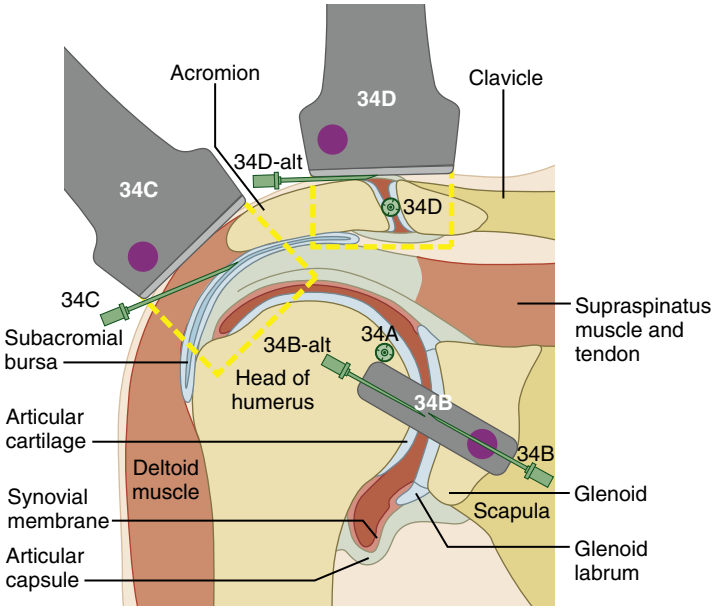

Fig. 34.1. Shoulder anatomic anterior view with ultrasound transducer and needle positions during image-guided injections described in our chapters. The depicted underlying structures are shaded in a yellow dashed line for US chapters. Purple dots indicate transducer orientation. (Please note that the USG GH joint injections ([34B] should actually be viewed from posterior.)
34A: Fluoroscopic-guided intraarticular glenohumeral (GH) joint, anterior approach
34B: USG intraarticular GH joint, posterior approach, medial to lateral
34B-alt: USG intraarticular GH joint, posterior approach, lateral to medial
34C: USG subacromial/subdeltoid bursa (SASDB) injection, lateral approach
34D: USG acromioclavicular (AC) joint intraarticular injection, anterior out-of-plane approach
34D-alt: USG AC joint intraarticular injection, lateral in-plane approach
34E: Suprascapular nerve injection (not shown in this figure)
34F: Biceps tendon sheath injection (not shown in this figure)

Suggested Readings

Peng PWH, Peter C. Ultrasound-guided interventional procedures in pain medicine: a review of anatomy, sonoanatomy, and procedures. Part III: shoulder. *Reg Anesth Pain Med*. 2011;36(6):592–605.

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CHAPTER 34A

Intraarticular Shoulder Injections—Anterior Approach: Fluoroscopic Guidance

John P. Batson, III, Stephen C. Johnson, and Michael B. Furman

Glenohumeral joint injections can be used for diagnosing intraarticular sources of pain (e.g., labral tears, degenerative joint disease), performing capsular distention for adhesive capsulitis, delivering contrast prior to magnetic resonance (MR) imaging, and instilling therapeutic agents into the joint space (e.g., corticosteroids, platelet rich plasma).

In this chapter, we describe the anterior approach targeting the upper medial aspect of the humeral head for access into the joint space. This "upper one-third" target for an intraarticular injection has been found to be accurate, safe, and less painful to patients compared with targeting the inferior aspect of the joint. This places the needle in the rotator cuff interval between the subscapularis and supraspinatus. Studies have also shown the upper medial approach to be quicker with less radiation exposure time. Initial contrast spread away from the needle tip, with contrast dispersion into the axillary recess, subscapular recess, and biceps tendon (BiTen) sheath, confirms an intraarticular injection.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 34A.1)

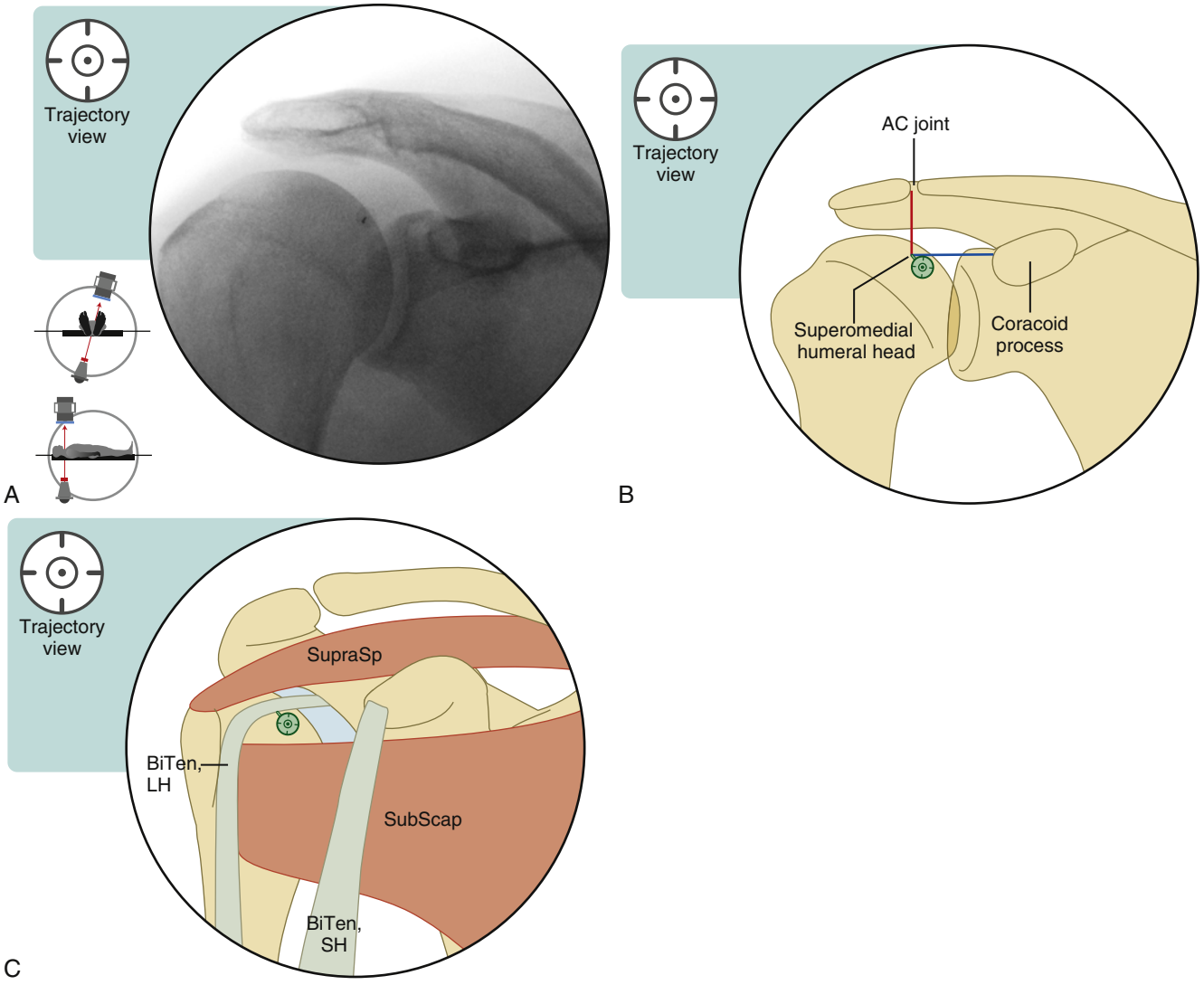

Fig. 34A.1. A, Fluoroscopic image of the trajectory view with the needle in position on the superomedial humeral head at the intersection of the AC joint and the superior aspect of the coracoid process. This intersection (*red and blue lines* in Fig. 34A.1B) corresponds to the upper one-third zone of the superomedial humeral head. The skin is marked at this point. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

The Trajectory View Is Also a Multiplanar View

- **Confirm the correct side** of the procedure (right or left shoulder).
- Position the patient supine on the fluoroscopy table.
- Place the shoulder in slight external rotation with the arm resting at the patient's side (palm up). Shoulder external rotation will minimize risk of puncturing the long head of the BiTen.
- A sandbag can be placed on the patient's fingers to help maintain this position.
- Position the C-arm over the target shoulder joint.
- The posteroanterior (PA) view of the shoulder is obtained.
- Slight contralateral oblique (~5–10 degrees) of the image intensifier may be used to optimize GH joint visualization.
- The optimal position is on the superomedial humeral head at the level of the coracoid process. This position corresponds to an imaginary line drawn at the **intersection of the AC joint and the superior aspect of the coracoid process.** Mark the skin at this site **(Fig. 34A.1A).**
- Because this is the trajectory view, **the needle should be placed parallel to the fluoroscopic beam.**
- Advance the needle until the needle tip contacts the humeral head.

Notes on Positioning in the Trajectory View

- There are typically no radiolucent structures that are safety considerations in this trajectory view.
- If the needle is placed too far medially, the labrum may be contacted.
- If the needle is placed too far laterally, the BiTen may be penetrated.

Optimal Needle Position in Multiplanar Imaging (Fig. 34A.2)

The Trajectory View Is Also a Multiplanar View

- To confirm the intraarticular needle position, oblique (ipsilateral or contralateral) or tilt (cephalad or caudal) the fluoroscope and obtain multiplanar confirmatory views.
- Alternatively, to confirm the intraarticular position of the needle, leave the fluoroscope in the trajectory (PA) view and take fluoroscopic spot views with the shoulder in external and internal rotation. However, this will be more uncomfortable for the patient.

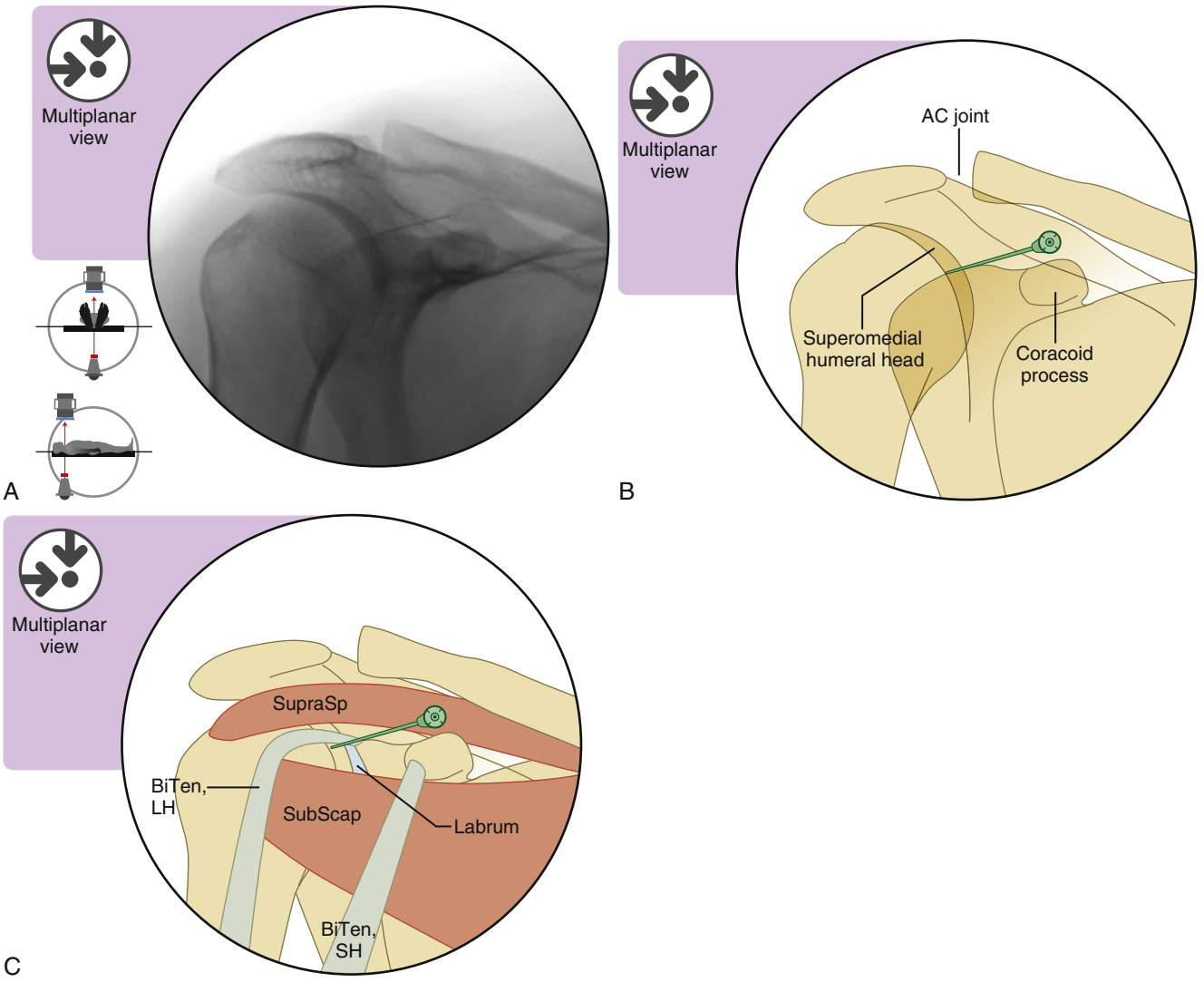

Fig. 34A.2. **A,** Fluoroscopic multiplanar oblique view. **B,** Radiopaque structures, multiplanar oblique view. **C,** Radiolucent structures, multiplanar oblique view.

Notes on Multiplanar Imaging

- After the needle tip contacts the humeral head, anesthetic can be administered for patient comfort. This also frequently gives a feel that the needle tip is already in the joint capsule as there should be little to no resistance with the injection.
- If resistance is met when injecting contrast or anesthetic, the needle tip may have penetrated the articular cartilage. Simply rotating the needle hub or slightly retracting the needle is often all that is needed.
- Patients with glenohumeral osteoarthritis have limited external rotation of the shoulder. They should be placed in a position of comfort with the arm resting at the side. The superomedial humeral head at the level of the coracoid can still be used as the target site; however, the needle may need to be "walked" more medial after bony contact to obtain intraarticular flow.

Notes on Shoulder Magnetic Resonance Arthrograms

- To avoid injection of air bubbles into the joint, drip a few drops of contrast into the needle hub and use contrast-filled extension tubing.
- The total volume for a shoulder arthrogram is typically 10 to 20 ml. Combinations with varying concentrations of saline, anesthetic, and a small amount of gadolinium are used. There is no consensus on the exact mixture, and this can vary from patient to patient depending on the diagnostic and therapeutic goals.
- After the injectate is administered, the extension tubing and needle should be flushed with normal saline or anesthetic prior to removal. This avoids a contrast-enhancing needle track, which may mimic a rotator cuff tear on the MR images.
- The time between the injection and MR imaging should be no longer than 90 minutes.

Optimal Images (Fig. 34A.3, 34A.4)

- Inject a small amount of contrast under live fluoroscopy to confirm intraarticular position and nonvascular injection.
- Contrast should flow freely away from the needle tip with little to no resistance.
- Ideal contrast flow will opacify the joint capsule, outline the articular surface, and may spread into the BiTen sheath.

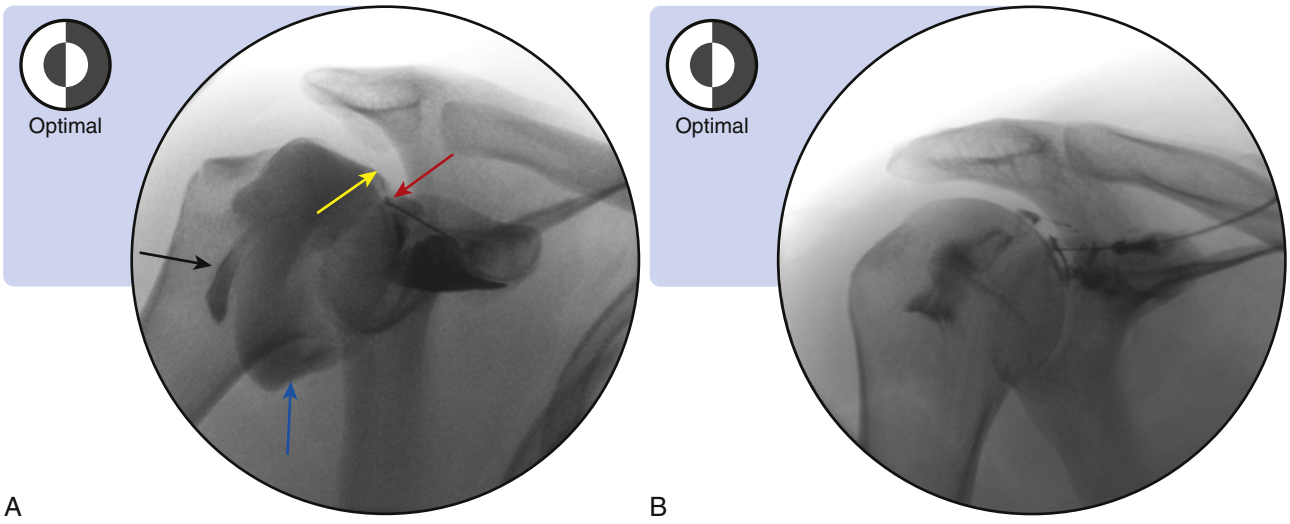

Fig. 34A.3. A, Optimal flow pattern and needle position. Needle point in upper one-third of the humeral head (*red arrow*). Contrast flow over the articular cartilage (*yellow arrow*). Contrast filling the inferior aspect of the joint capsule (*blue arrow*). Spillover of contrast along the biceps tendon sheath (*black arrow*). **B,** Optimal flow pattern in a different patient showing ideal contrast flow in the glenohumeral joint.

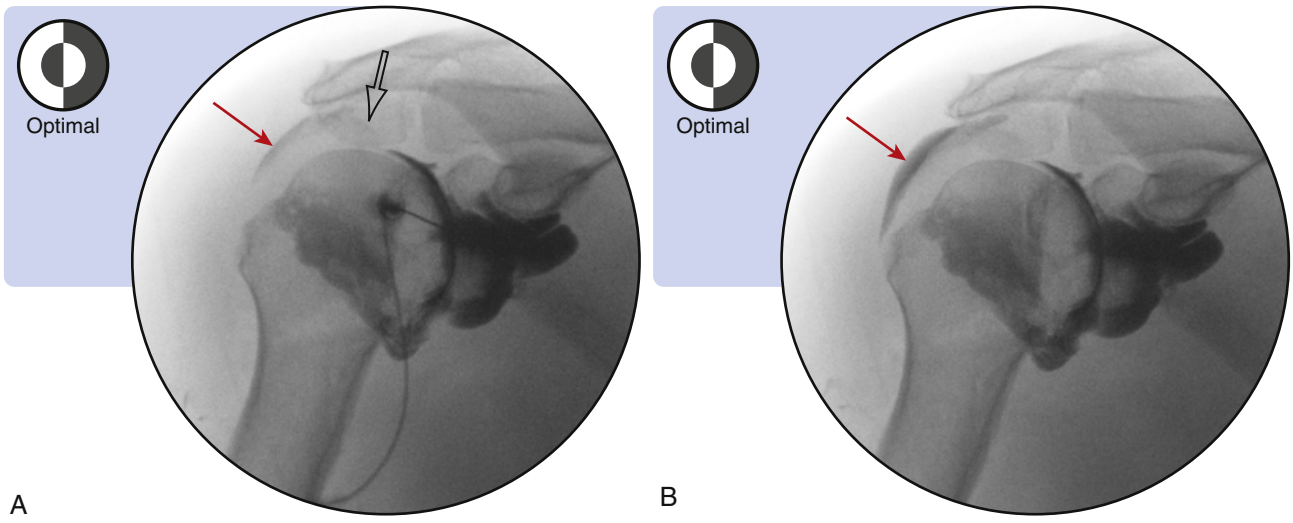

Fig. 34A.4. Optimal intraarticular flow pattern during arthrogram with 8 cc of contrast (prior to computed tomography) demonstrating full thickness tear with flow into subdeltoid/subacromial space. **A,** Needle point in the upper one-third of the humeral head. Contrast flows through the tear (*open arrow*) into the subdeltoid/subacromial space (*red arrow*). **B,** Same case with needle removed. Note the additional contrast in the subdeltoid/subacromial space (*red arrow*).

Suboptimal Image (Fig. 34A.5)

- Avoid a vascular injection. If nonvascular flow cannot be obtained, the procedure should be terminated without the injection of a steroid.
- A subdeltoid injection may be obtained because of a tear (34A.4) or because of needle tip placement into the subdeltoid bursa instead of the glenohumeral joint.

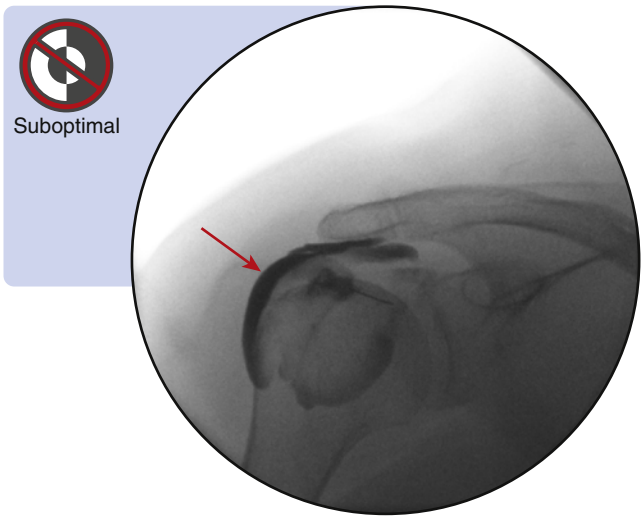

Fig. 34A.5. Suboptimal flow pattern. Contrast is filling the subacromial/subdeltoid bursa (*red arrow*) rather than the joint capsule. Needle likely needs to be advanced further to reach bony intraarticular contact.

Reference

1. Redondo MV, Berná-Serna JD, Campos PA, et al. MR arthrography of the shoulder using an anterior approach: optimal injection site. *AJR Am J Roentgenol*. 2008;191(5):1397–1400.

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CHAPTER 34B

Intraarticular Shoulder Injection—Posterior Approach: Ultrasound Guidance

Jackson Liu and Naimish Baxi

Using ultrasound, the glenohumeral (GH) joint can be accessed from either an anterior or posterior approach. The posterior approach, medial to lateral, described in this chapter, can prevent injury to the labrum. We also demonstrate an alternate posterior, lateral to medial approach with limited figures (Fig. 34B.4). Fluoroscopic visualization after needle placement and contrast injection can be confirmatory.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 34B.1)

- Patient is positioned side-lying on contralateral shoulder.
- Patient's ipsilateral arm should be internally rotated and adducted across the chest to open the joint space.
- Interventionalist stands behind the patient (Fig. 34B.1E).
- Ultrasound image is in front of the patient on the opposite side of the interventionalist and in line with the transducer (see Fig. 34B.1A and Chapter 4).
- Begin by placing the transducer over the posterolateral shoulder **parallel and just inferior to the scapular spine**.
- Identify the humeral head, GH joint capsule, labrum, and bony glenoid with overlying infraspinatus and deltoid muscles (Fig. 34B.1B,C).
- **Rotate the transducer** to optimize simultaneous visualization of the above structures.
- Insert the needle from an **inferomedial to a superolateral direction** toward the joint capsule.
- While visualizing the needle tip in-plane, advance until it enters the capsule and lies **adjacent to the labrum** (Fig. 34B.1B,C).
- If resistance is encountered while administering the injectate, the needle may be embedded in cartilage, labrum, or within the capsule. Slightly withdrawing or advancing the needle while injecting will produce a loss of resistance and improved flow of injectate. Confirm the flow is subcapsular and intraarticular.

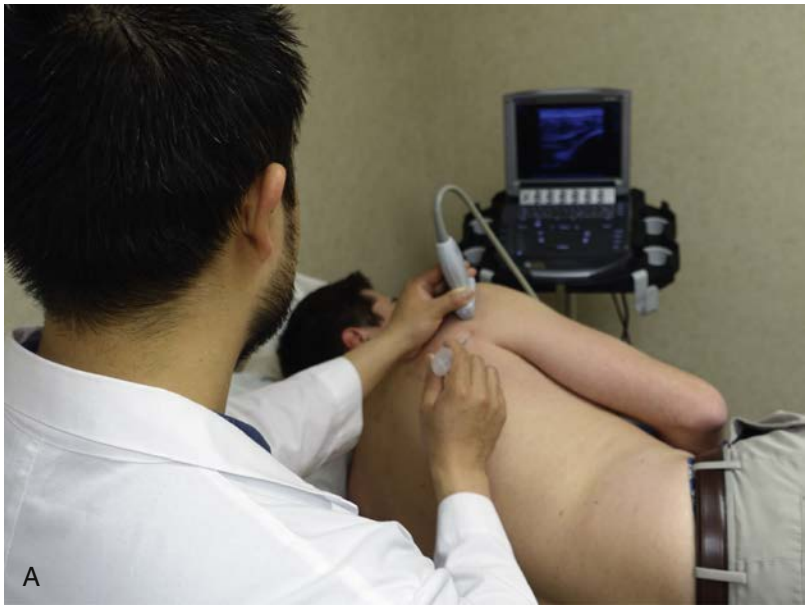


Fig. 34B.1. A, Room, interventionalist, transducer, and US unit setup for USG intraarticular shoulder injection.

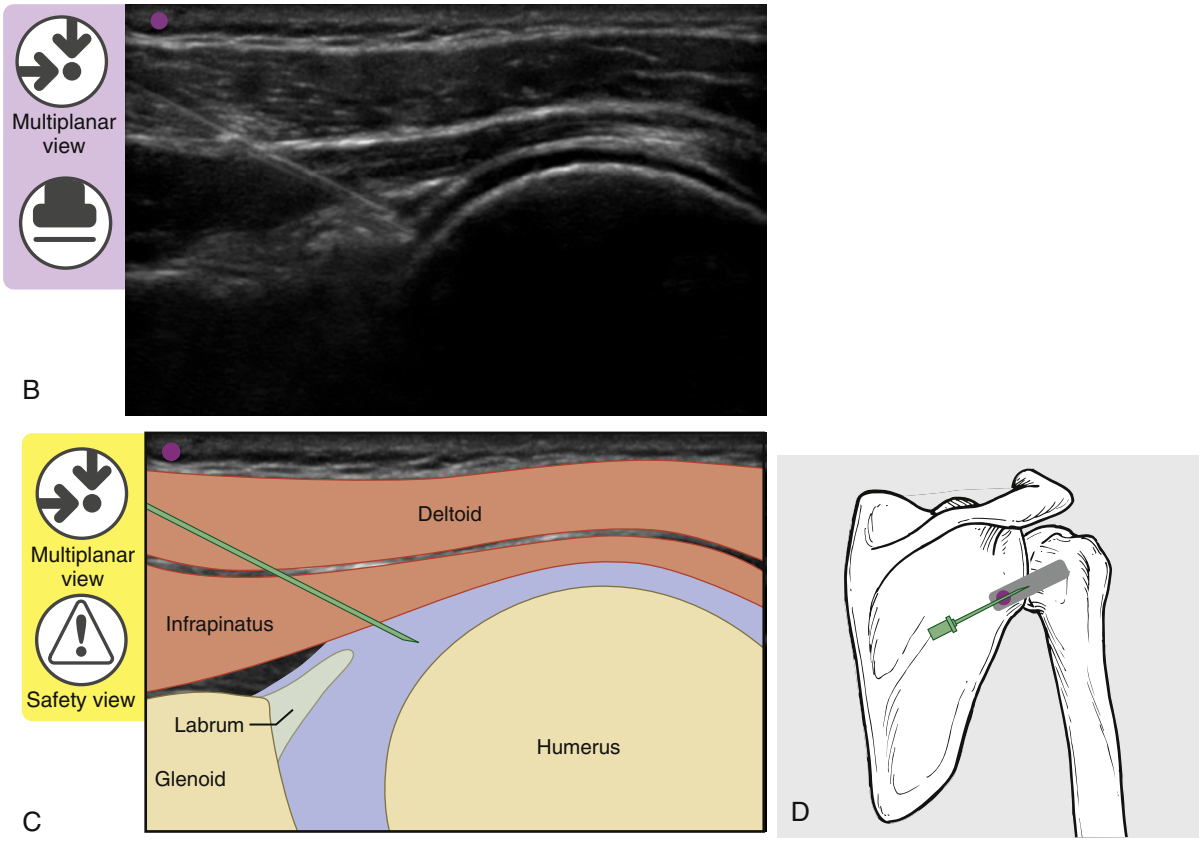


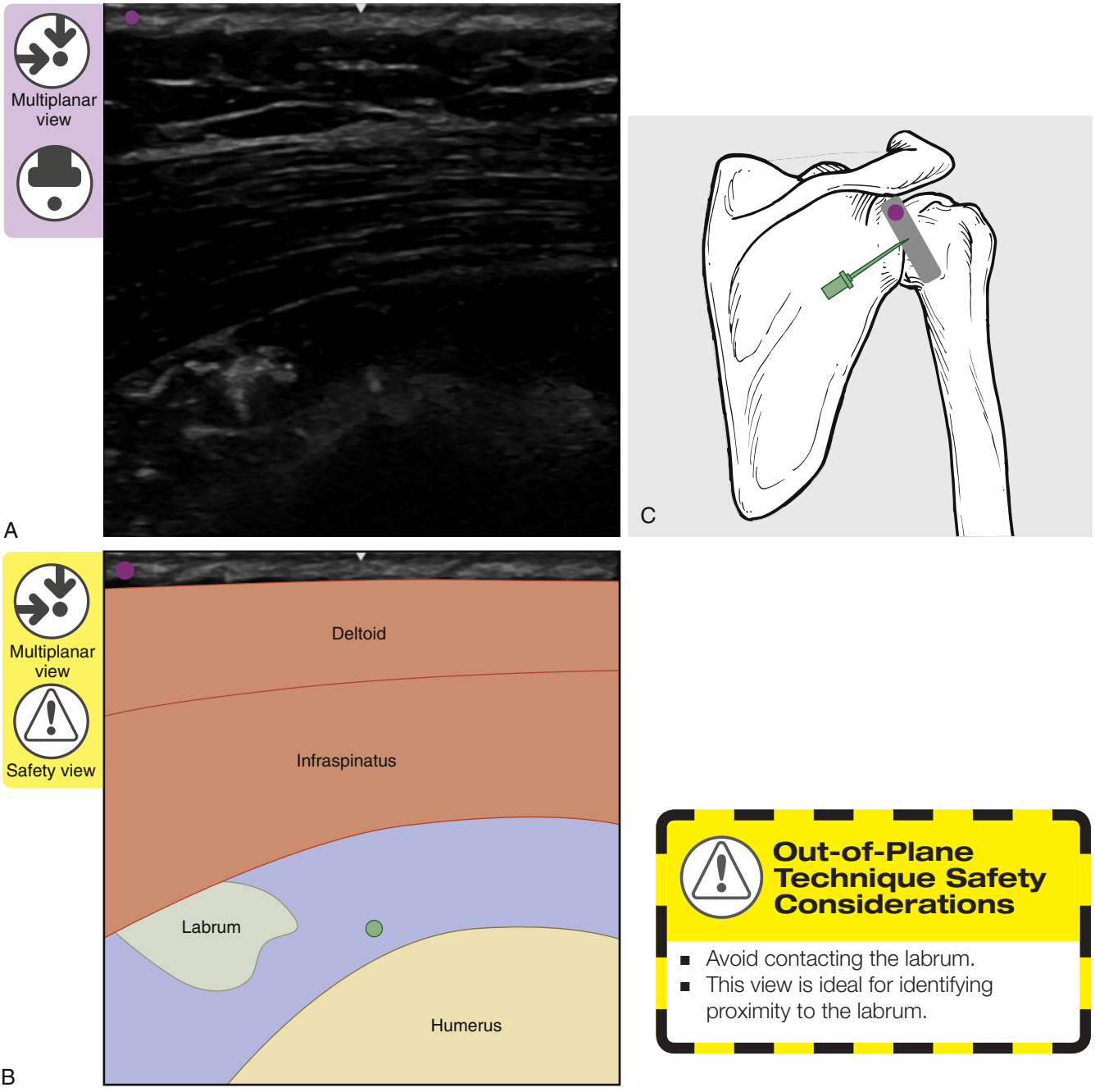
Fig. 34B.1, Cont'd B, Ultrasound image of intraarticular glenohumeral joint needle placement adjacent to the labrum. **C,** Drawing of relevant structures. Needle is green; blue indicates the joint capsule, cartilage, and space. **D,** Skeleton showing proper placement of ultrasound transducer and needle.

In-Plane Technique Safety Considerations

- Avoid penetrating the labrum.
- If the needle is too medial, it may end up in or near the spinoglenoid notch containing the suprascapular nerve, artery, and vein.
- If the needle is too inferior it may block the axillary nerve.

Out-of-Plane Confirmation (Fig. 34B.2)

- After subcapsular placement with in-plane technique, rotate the transducer 90 degrees to an out-of-plane view to re-confirm subcapsular needle tip position.
- If the needle tip is well placed deep to the capsule, it should not be difficult to rotate the transducer to locate the tip as migration is unlikely.
- Tip should be visualized deep to the infraspinatus, superficial to the humeral head, and adjacent to the labrum.



Out-of-Plane Technique Safety Considerations

- Avoid contacting the labrum.
- This view is ideal for identifying proximity to the labrum.

Fig. 34B.2. A, Ultrasound image of intraarticular glenohumeral joint needle placement adjacent to the labrum in short axis. **B,** Drawing of relevant structures. Needle is green; asterisk indicates the joint capsule, cartilage, and space. Note that the joint capsule is distended with injectate. **C,** Skeleton showing proper placement of ultrasound transducer for out-of-plane confirmation.

Optimal Images (Fig. 34B.3, 34B.4)

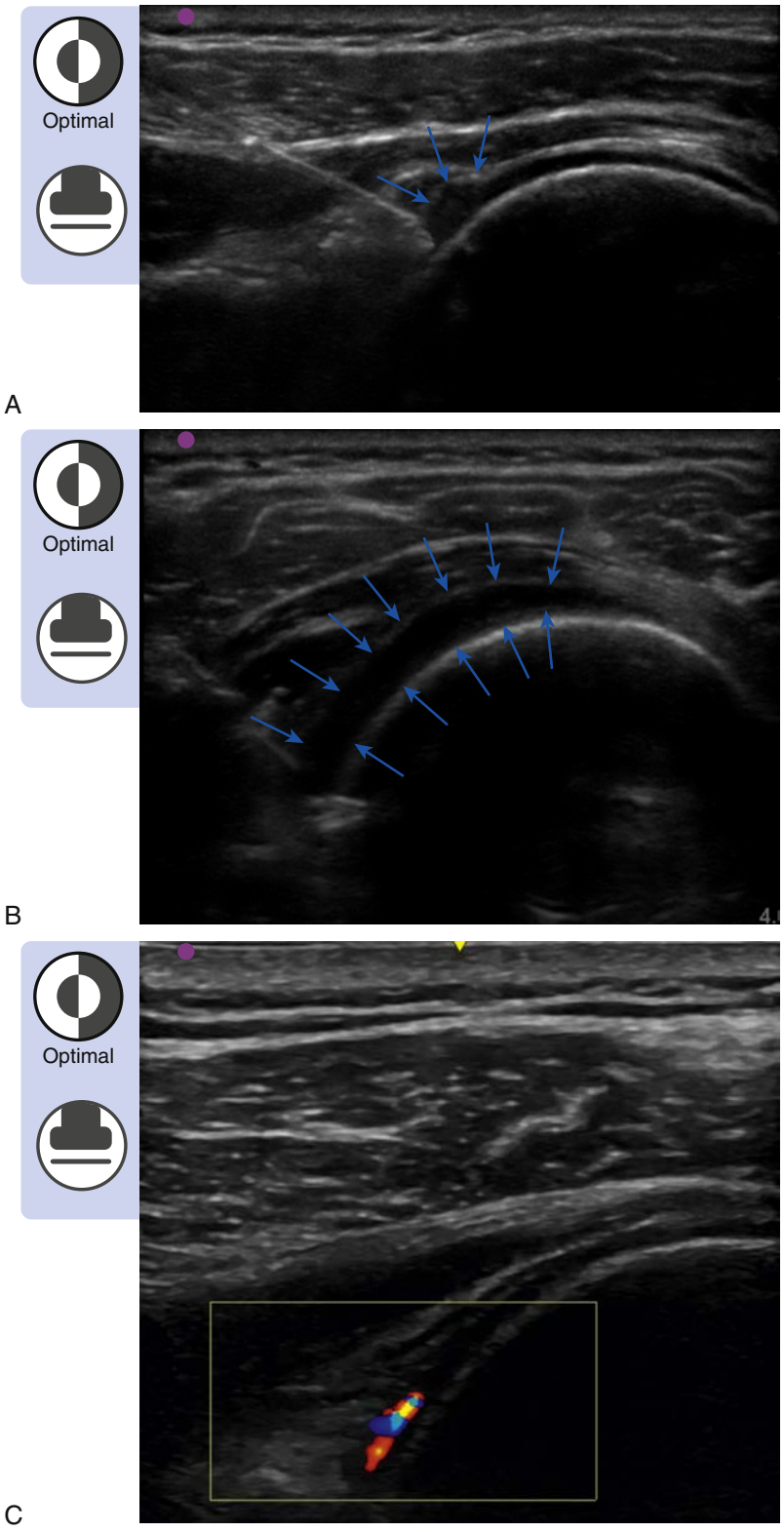


Fig. 34B.3. Optimal ultrasound-guided intraarticular glenohumeral injection showing **A,** focal capsular distention during initial injection (*arrows*). **B,** Diffuse capsular distention after the administration of injectate (*arrows*). **C,** Subcapsular flow with color Doppler; note that needle is not well visualized on this image.

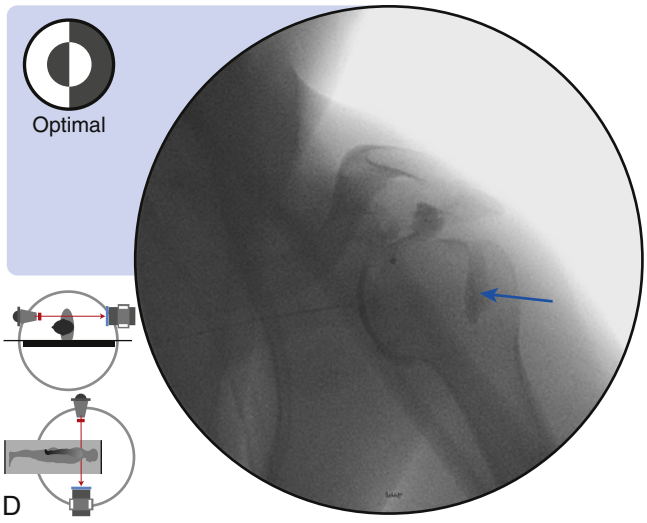


Fig. 34B.3, Cont'd D, Fluoroscopic confirmation of contrast flow outlining the glenohumeral joint after an USG GH joint inection. Note the medial to lateral needle trajectory. Arrow indicates flow along the biceps tendon sheath.

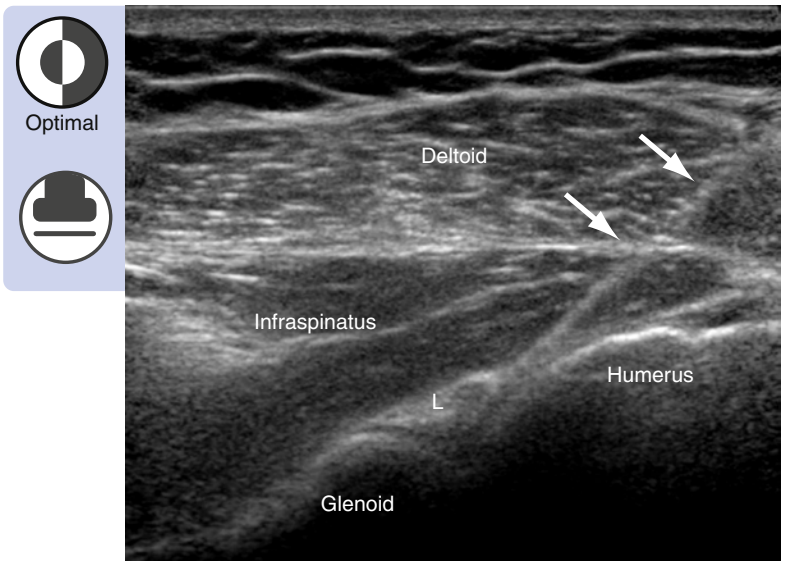


Fig. 34B.4. Needle placement using an alternate lateral to medial approach (arrows not described in this chapter); note sub-labral needle position. *L*, Labrum. (Courtesy of Dr. Marko Bodor, MD.)

Suboptimal Image (Fig. 34B.5)

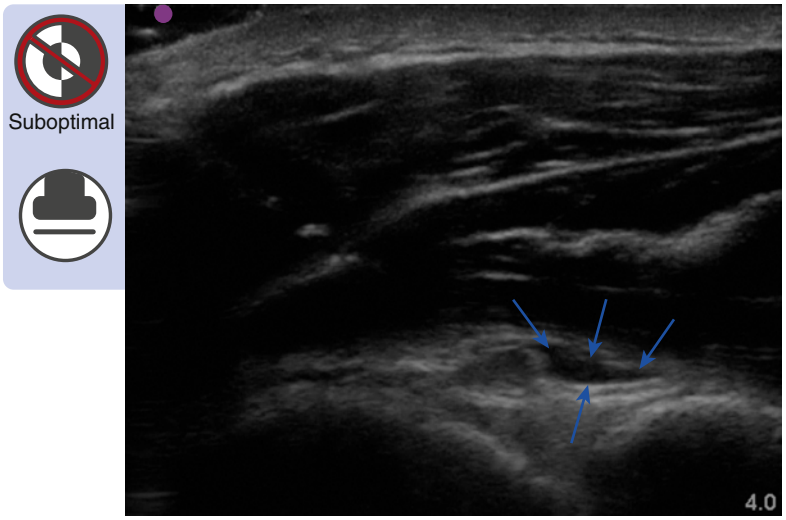


Fig. 34B.5. Suboptimal injection showing extracapsular pooling of injectate superficial to the labrum during initial injection (*arrows*). This can occur when the needle tip and/or glenohumeral joint is not properly visualized prior to injection.

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CHAPTER 34C

Shoulder/Subacromial–Subdeltoid Bursa Injection—Lateral Approach: Ultrasound Guidance

Jackson Liu and Naimish Baxi

The subacromial–subdeltoid bursa (SASDB) can be well visualized with the transducer placed over the lateral aspect of the shoulder with the supraspinatus tendon and acromion in the field of view. This footprint allows for accurate injection into the bursa while avoiding a direct tendon or deltoid muscle injection.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 34C.1)

- Patient is positioned side lying (shown in 34C.1A), sitting, or supine (not shown).
- Patient's arms should be positioned comfortably at the sides.
- Ultrasound image is on the opposite side of the interventionalist and in line with transducer (see Fig. 34C.1A and Chapter 4).
- Begin by placing the transducer over the lateral acromion **with the supraspinatus tendon in view**.
- Identify the acromion, humerus, and supraspinatus tendon with overlying deltoid musculature; the SASDB is visualized deep to the deltoid but superficial to the supraspinatus, typically as a thin hypoechoic layer (Fig. 34C.1B,C).
- **Tilt and heel-toe** the transducer to optimize visualization of the bursa.
- With the transducer in the coronal or coronal–oblique plane, long axis to the orientation of the supraspinatus, insert the needle from a **lateral to medial direction** toward the bursa.
- While visualizing the needle tip in-plane, advance until it enters the SASDB and lies just **superficial to the supraspinatus tendon** (Fig. 34C.1A to D).
- If the needle is too superficial it may be located in the deltoid muscle.
- If resistance is encountered while administering the injectate, the needle may be embedded in the supraspinatus tendon. Slightly withdrawing the needle while injecting will produce a loss of resistance and flow of the injectate.

Fig. 34C.1. A, Room, interventionalist, transducer, and US unit set up for USG subacromial/subdeltoid bursa injection.

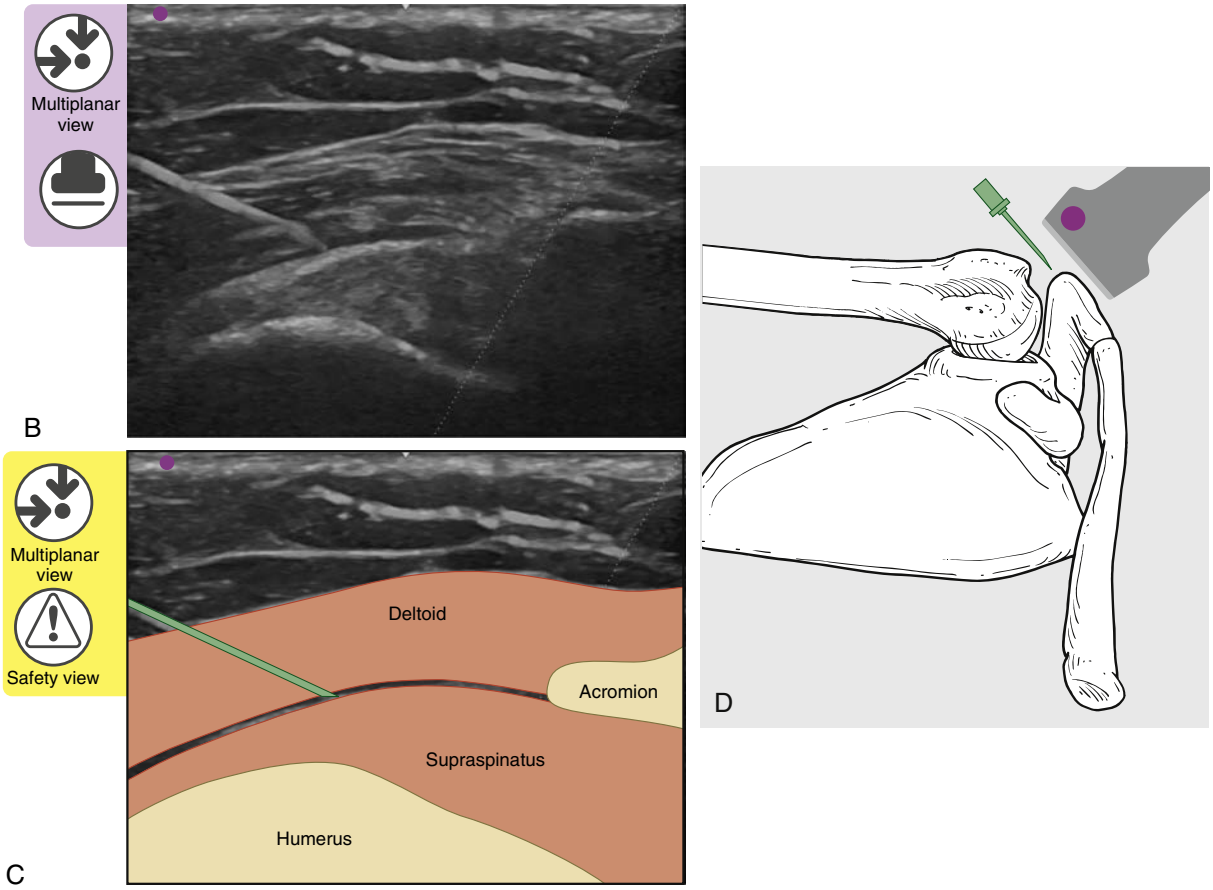

Fig. 34C.1, cont'd B, Ultrasound image of the subacromial–subdeltoid bursa (SASDB) needle placement superficial to the supraspinatus tendon with an in-plane approach. **C,** Drawing of relevant structures. Needle is green; note the SASDB space.**D,** Skeleton showing the proper placement of ultrasound transducer and needle.

In-Plane Technique Safety Considerations

- Avoid penetrating the supraspinatus tendon which is immediately deep to the bursa.
- There are no neurovascular structures that must be avoided in this approach.

Out-of-Plane Confirmation (Fig. 34C.2)

- After bursal placement with in-plane technique, rotate the transducer 90 degrees to an out-of-plane view to re-confirm the bursal needle tip position.
- If the needle tip is well placed within the bursa, it should not be difficult to rotate the transducer to locate the tip as migration is unlikely.
- Tip should be visualized deep to the deltoid and superficial to the supraspinatus.

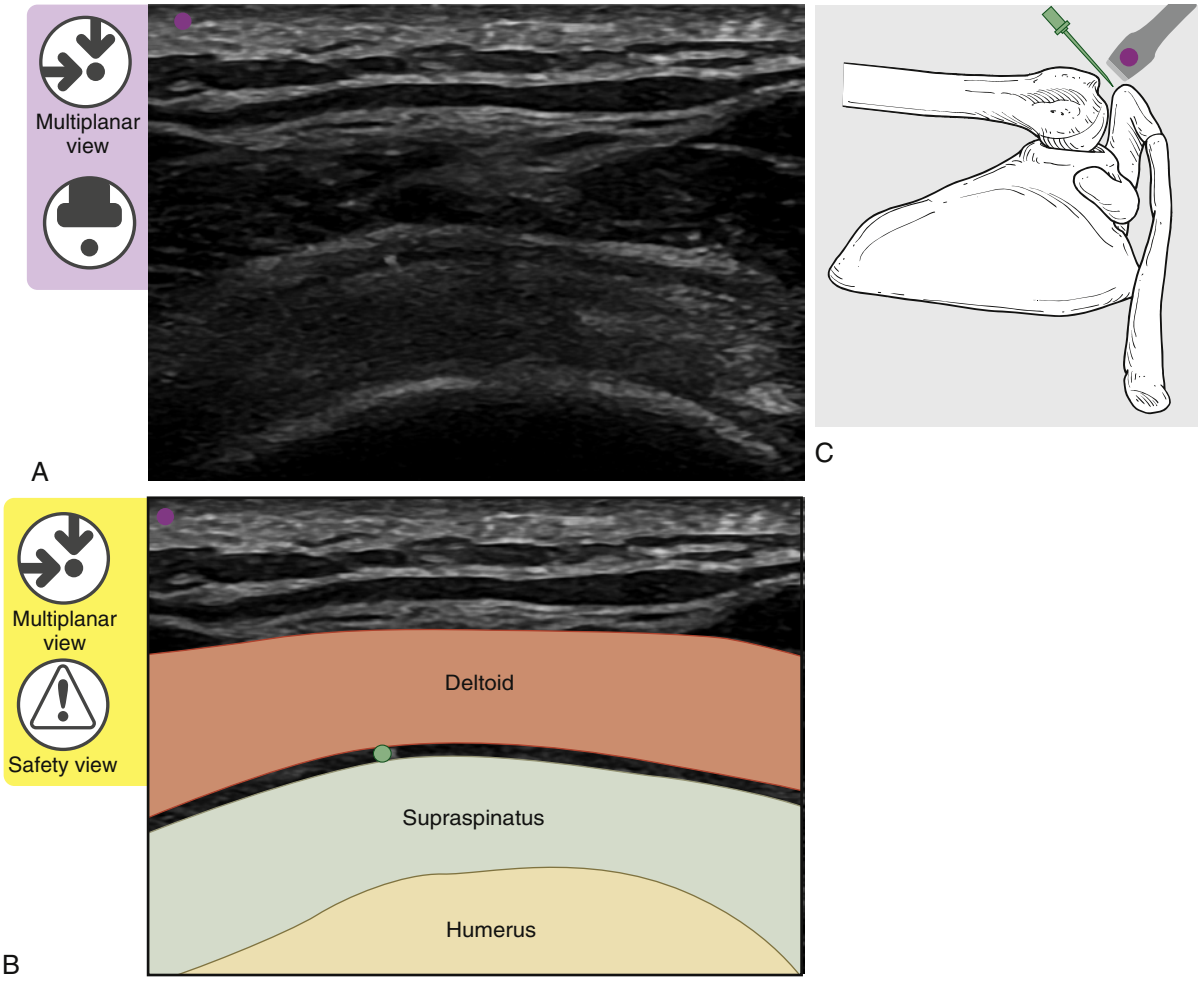

Fig. 34C.2. A, Ultrasound image of the subacromial–subdeltoid bursa (SASDB) needle placement with an out-of-plane confirmation. **B,** Drawing of relevant structures. Needle is green within the SASDB. **C,** Skeleton showing proper placement of ultrasound transducer and needle for out-of-plane confirmation.

Out-of-Plane Technique Safety Considerations

- Avoid penetrating the supraspinatus tendon, which is immediately deep to the bursa.
- There are no neurovascular structures that must be avoided in this approach.

Optimal Images (Fig. 34C.3)

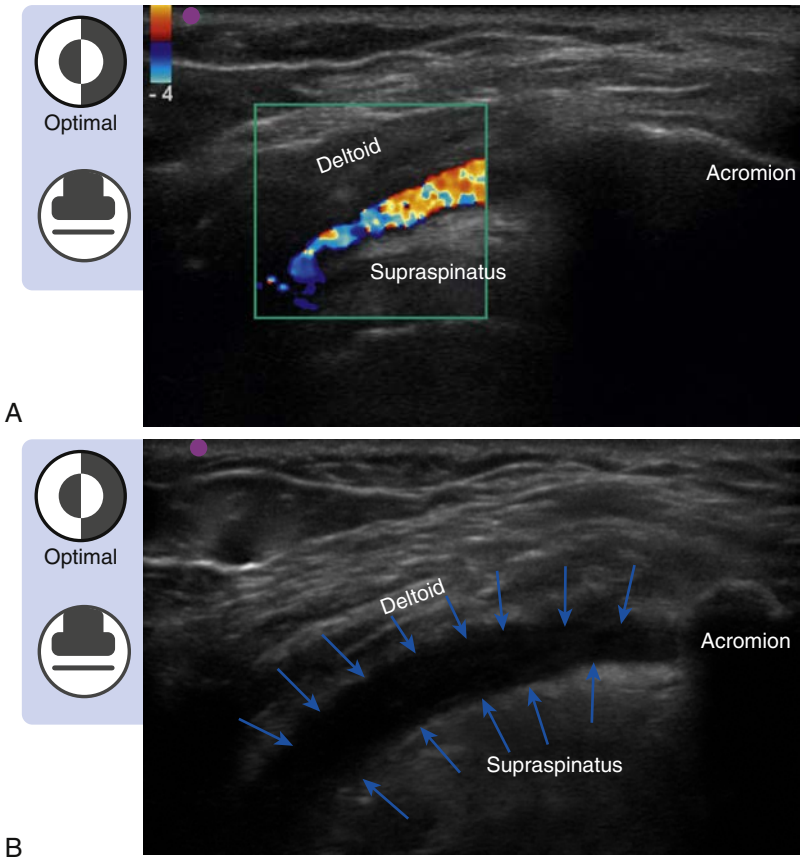

Fig. 34C.3. Optimal subacromial–subdeltoid bursa injection showing **A,** bursal flow with color Doppler. **B,** Bursal distention after the administration of injectate (arrows).

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CHAPTER 34D

Shoulder/ Acromioclavicular Joint Injection—Out-of-Plane Approach: Ultrasound Guidance

Jackson Liu, Naimish Baxi, and John P. Batson, III

There are several approaches to inject the acromioclavicular joint (ACJ). The out-of-plane technique, anterior to posterior, short axis to the joint, described in this chapter is an effective approach to deliver a therapeutic agent into the intraarticular space while avoiding nearby structures including the acromioclavicular and coracoclavicular ligaments. The joint can also be approached in-plane either lateral to medial (demonstrated in Fig. 34D.4 but not described) or anterior to posterior. A hypoechoic fluid collection, known as the *geyser sign,* can indicate joint pathology and can further help visualize accurate needle placement.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Out-of-Plane Technique (Fig. 34D.1)

- Patient is positioned supine (shown in Fig 34D.1A) or sitting.
- Patient's arms should be positioned comfortably at the sides.
- Interventionalist stands to the ipsilateral side of the patient (Fig. 34D.1A).
- Ultrasound image is on the opposite side of the interventionalist and in line with transducer (see Fig. 34D.1A and Chapter 4).
- Begin by placing the transducer over the ACJ in the **coronal plane;** this can be assisted by palpating the clavicle and following it laterally until the joint is located.
- Identify the ACJ and capsule, which appears as a hypoechoic space between the acromion and clavicle (Fig. 34D.1B,C).
- **Translate the transducer** in the coronal plane to optimize visualization of the joint.
- With the transducer coronal, insert the needle from an **anterior to posterior direction** toward the joint.
- Advance until the needle tip is visualized out-of-plane as it enters the ACJ and is **visualized between the acromion and clavicle** (Fig. 34D.1B,C).
- If resistance is encountered while administering injectate, the needle may be embedded in joint capsule or cartilage. Slightly withdrawing or advancing the needle while injecting will produce a loss of resistance and flow of injectate.

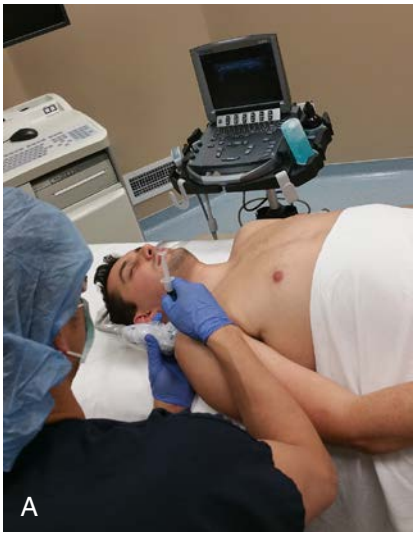

Fig. 34D.1. A, Room, interventionalist, trasducer, and ultrasound unit setup for ACJ injection in the supine position.

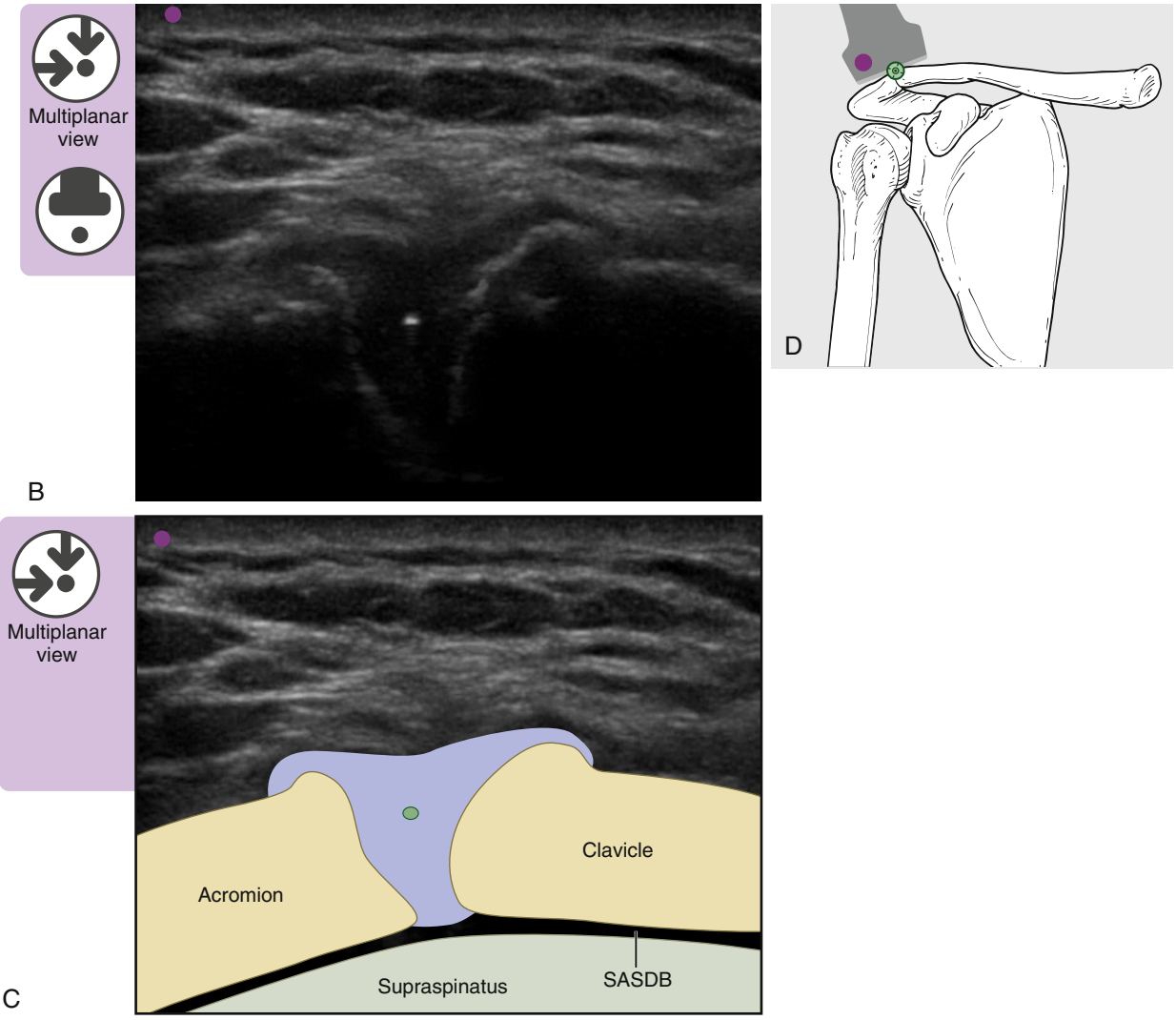

Fig. 34D.1,cont'd **B,** Ultrasound image of the acromioclavicular joint needle placement between the acromion and clavicle, out-of-plane, short axis to joint. **C,** Drawing of relevant structures. Needle is green; blue indicates joint capsule, cartilage, and space. **D,** Skeleton showing proper placement of ultrasound transducer.

Out-of-Plane Technique Pearls

- Needle should not be directed too inferiorly, which may penetrate the subacromial–subdeltoid bursa (SASDB).
- There are no neurovascular structures that must be avoided in this approach.

In-Plane Confirmation (Fig. 34D.2)

- After joint placement with an out-of-plane technique, rotate the transducer 90 degrees to an in-plane view to re-confirm joint needle tip position.
- If the needle tip is well placed within the capsule, it should not be difficult to rotate the transducer to locate the tip as migration is unlikely.
- Tip should be visualized inside the joint space.

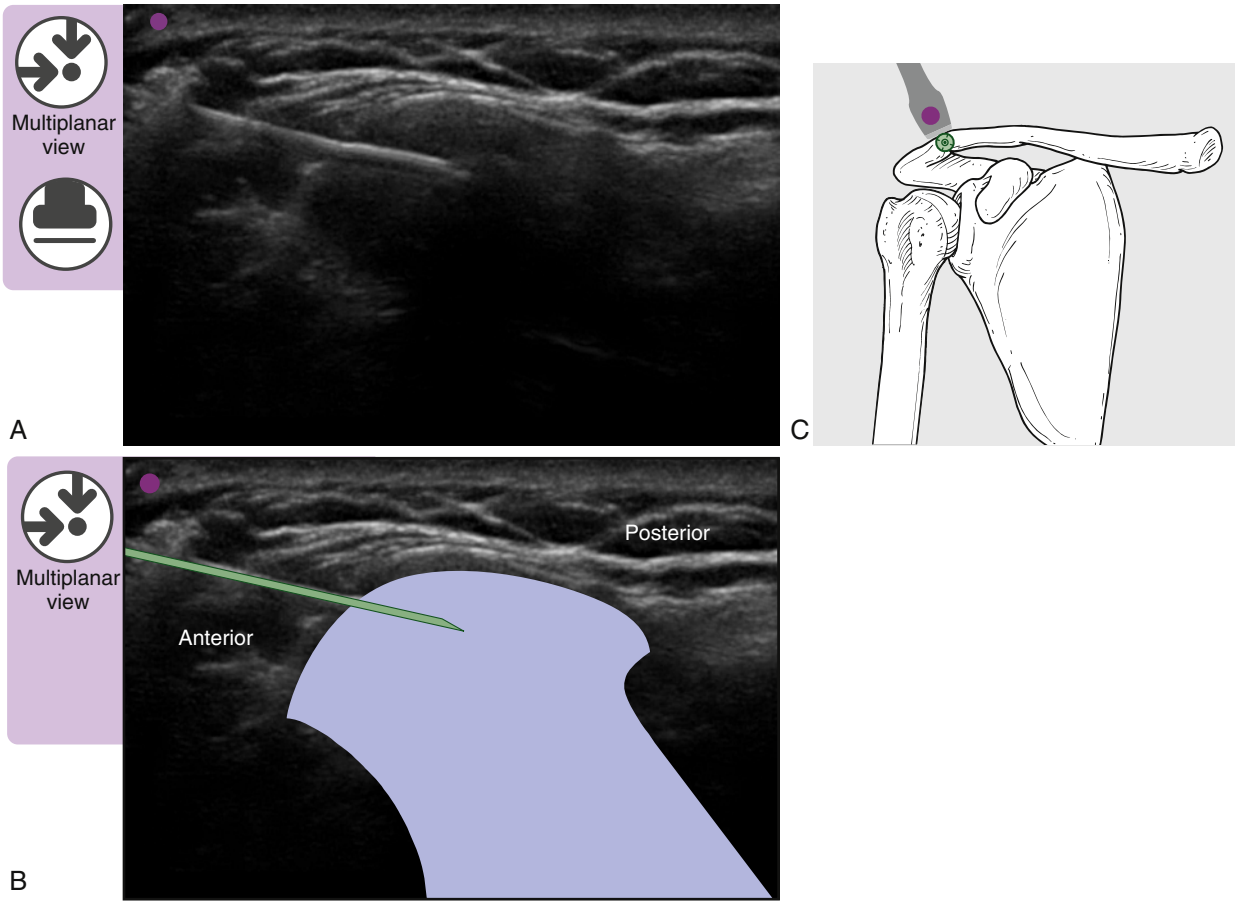

Fig. 34D.2. A, Ultrasound image of the acromioclavicular joint needle placement in-plane to needle, short axis to joint for in-plane confirmation. **B,** Overlayed drawing of joint capsule. Needle is green; blue indicates joint capsule, cartilage, and space. **C,** Skeleton showing proper placement of ultrasound transducer for in-plane confirmation.

In-Plane Confirmation Pearls

- Take care not to advance through the joint.
- There are no neurovascular structures that must be avoided in this approach.

Optimal Images (Fig. 34D.3)

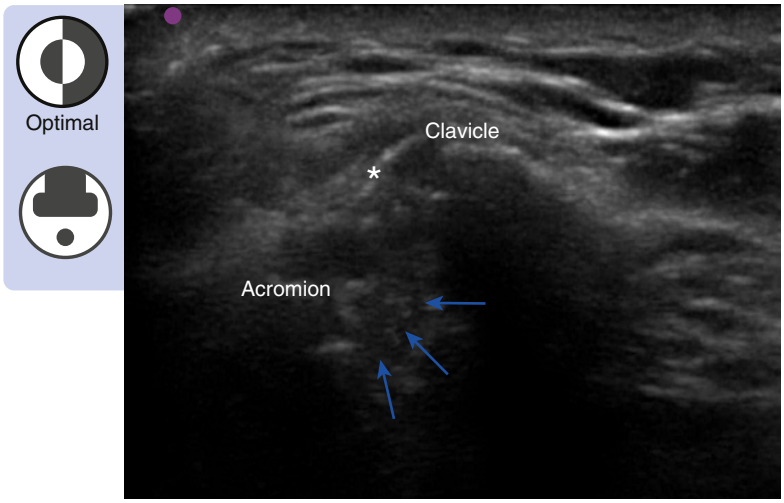

Fig. 34D.3. Joint filled with steroid injectate which appears hyperechoic (*arrows*) after an out-of-plane injection. Asterisk indicates the joint capsule, cartilage, and space.

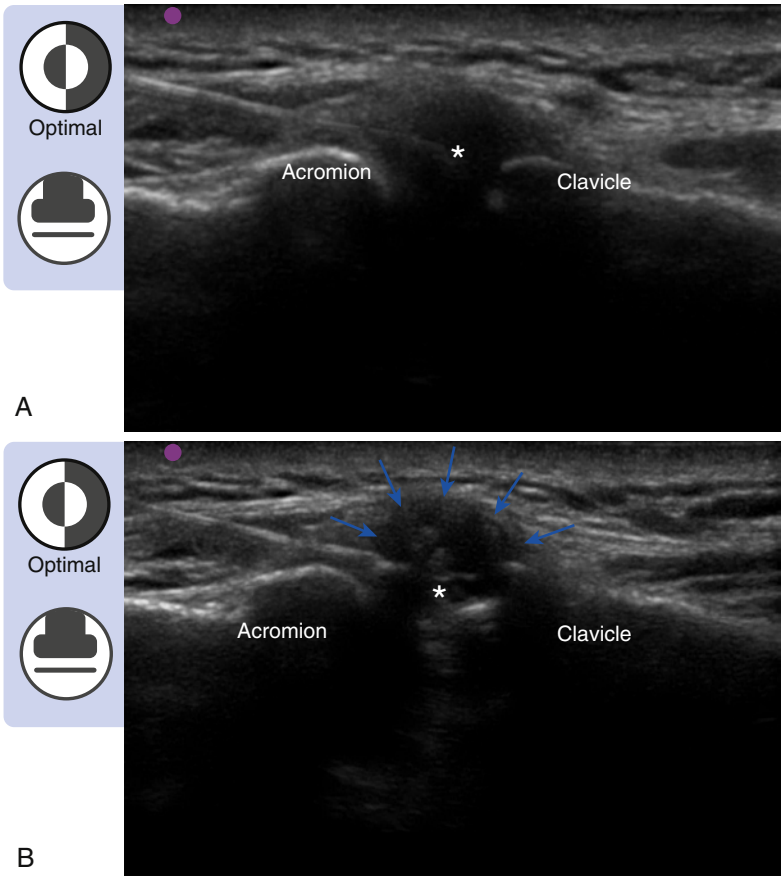

Fig. 34D.4. Alternative in-plane to needle, short axis to joint, lateral to medial approach with optimal acromioclavicular joint injection showing, **A,** needle placement. This can also be done with a gel standoff technique (not shown here, but described and demonstrated in Chapter 4, Fig. 4.23). **B,** Capsular distention (*arrows*) during steroid injectate administration, which appears hyperechoic in the joint. Asterisk indicates the joint capsule, cartilage, and space.

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CHAPTER 34E

Suprascapular Nerve Injection—In-Plane Approach: Ultrasound Guidance

Stephen C. Johnson, Melinda S. Loveless, and Michael B. Furman

The suprascapular nerve (SSN) is a mixed nerve formed primarily by the C5 and C6 nerve roots and the upper trunk of the brachial plexus. The SSN travels deep to the trapezius (Trap) muscle and then enters the supraspinatus fossa. It then courses through the suprascapular notch underneath the superior transverse scapular ligament (STSL). Here motor branches innervate the supraspinatus muscle and sensory branches are provided to the posterior glenohumeral joint capsule, acromioclavicular joint, subacromial bursa, and the coracoclavicular and coracoacromial ligaments. The SSN then passes through the spinoglenoid notch to the infraspinatus fossa where terminal motor branches are given to the infraspinatus muscle.

A suprascapular nerve block (SSNB) may be used for postoperative pain control after shoulder surgery. SSNB has also been used for chronic shoulder pain related to osteoarthritis, rheumatoid arthritis, adhesive capsulitis, and rotator cuff lesions.

This chapter describes an in-plane technique, short axis to the SSN in the suprascapular notch, with out-of-plane confirmation. Safety considerations will also be highlighted including the use of Doppler imaging to avoid intravascular injection.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 34E.1)

- Patient is positioned seated (shown in 34E.1A) or prone.
- The patient is seated with the ipsilateral hand resting on the contralateral shoulder. With this setup, the ultrasound image is placed in front of the patient **(Fig. 34E.1A)**.
- Alternatively, the patient may be prone with the arms positioned comfortably at the sides or hanging down (not shown).
- Interventionalist stands behind the patient **(Fig. 34E.1A)**.
- Ultrasound image on the opposite side of interventionalist and in line with the transducer (see 34E.1A and Chapter 4).
- Begin by placing the transducer parallel to the spine of the scapula in a coronal oblique plane overlying the supraspinatus muscle and the suprascapular fossa **(Fig. 34E.1D)**.
- Identify the coracoid process of the scapula and the supraspinous fossa (forming the suprascapular notch), STSL, supraspinatus muscle, and overlying Trap muscle **(Fig. 34E.1B,C)**.
- The SSN is visualized deep to the STSL. The suprascapular artery runs superficial to the STSL **(Fig. 34E.1C)**.
- Heel-toe the transducer to optimize visualization of the SSN.
- With the transducer in the coronal oblique plane overlying the supraspinatus muscle, insert the needle from a **medial to lateral direction** toward the SSN at the level of the suprascapular notch.
- While visualizing the needle in-plane, advance until the needle tip is advanced through the STSL **(Fig. 34E.1B,C)**.

Fig. 34E.1. A, Interventionalist, transducer, and ultrasound unit setup for suprascapular nerve injection in the seated position. This can also be performed in the prone position (not shown.)

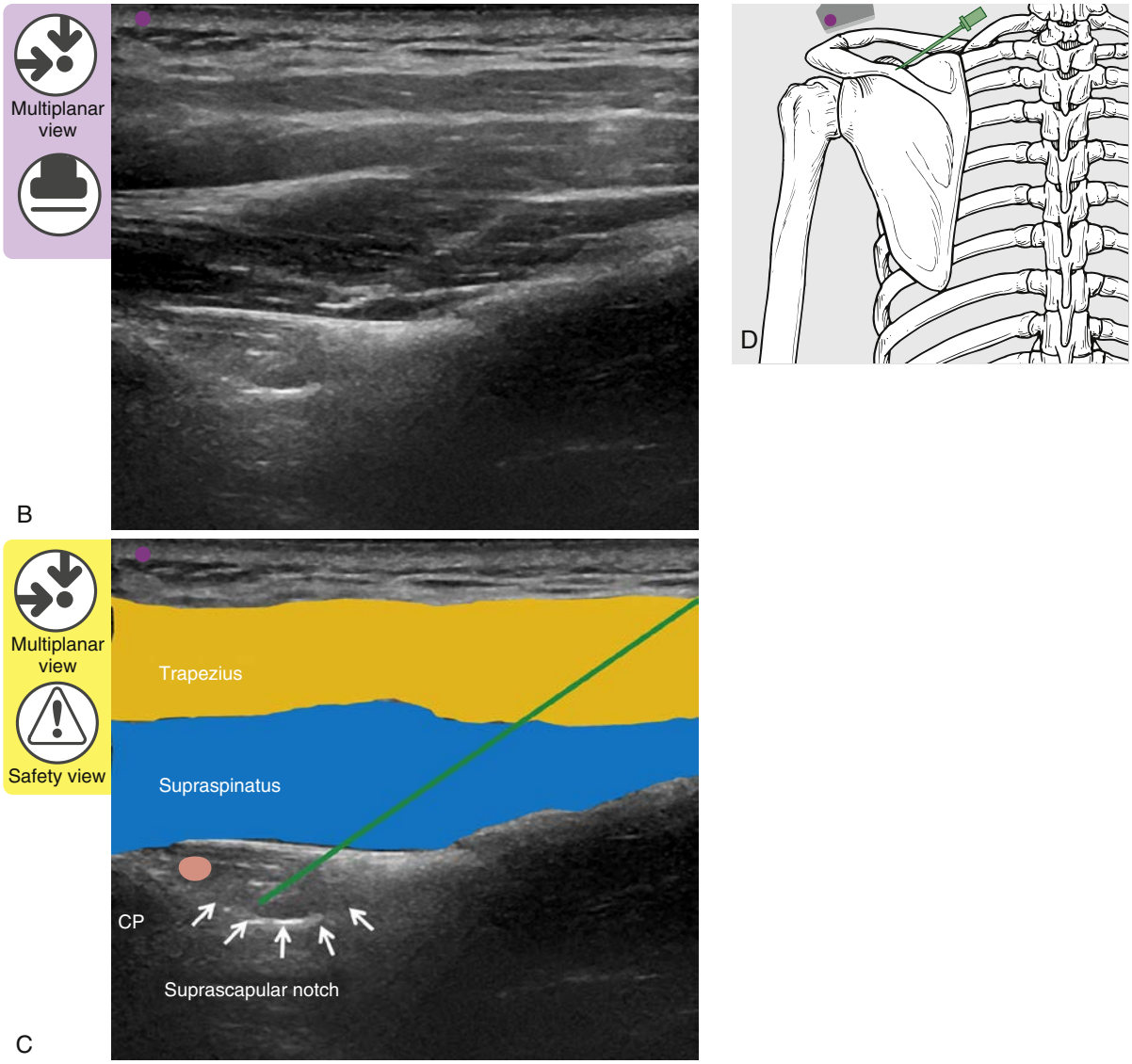


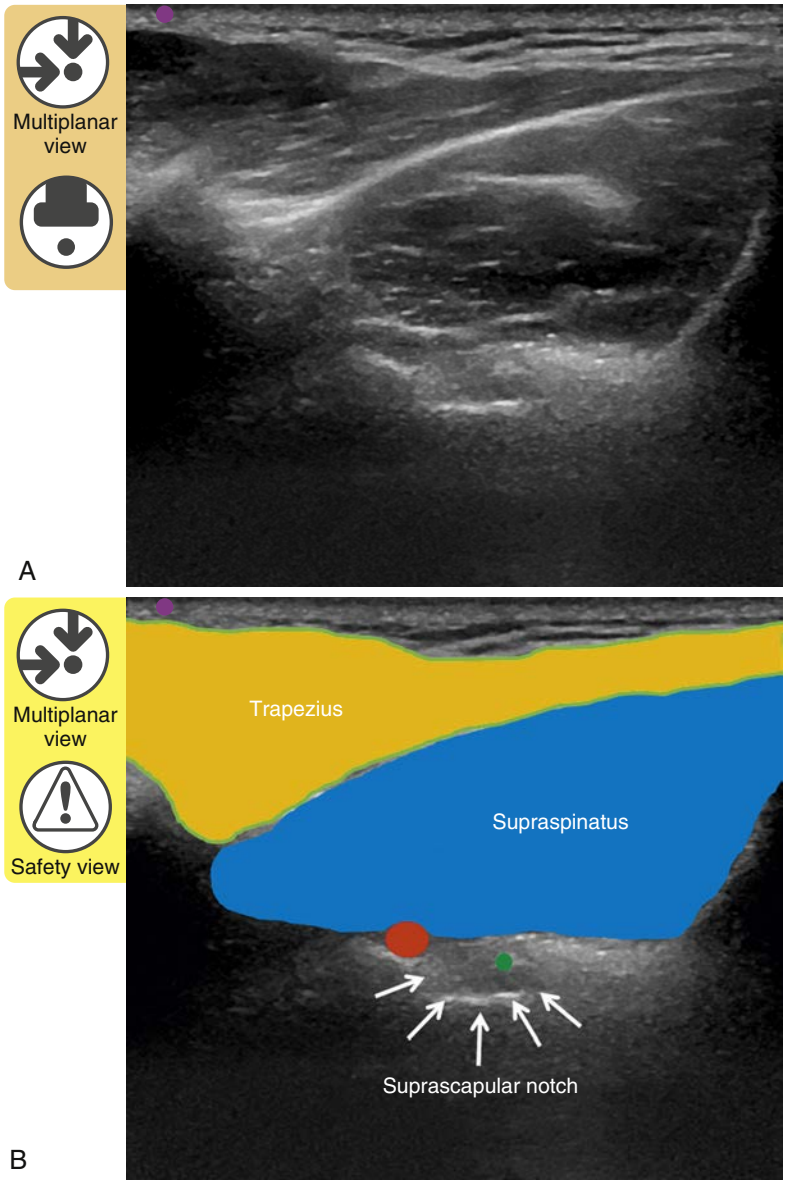
Fig. 34E.1, cont'd B, Ultrasound image of in-plane needle placement at the level of the suprascapular notch, deep to the superior transverse scapular ligament. **C,** Drawing of relevant structures. CP, coracoid process. **D,** Skeleton showing proper ultrasound transducer and needle placement. The needle tip target is just ventral to the scapular spine.

In-Plane Safety Considerations

- If the needle is superficial to the STSL, there is a risk of vascular injection into the suprascapular artery. Doppler imaging should be used to identify the artery.

Out-of-Plane Confirmation (Fig. 34E.2)

- After placement deep to the STSL, rotate the transducer 90 degrees to an out-of-plane view to re-confirm supra-scapular notch needle tip position **(Fig. 34E.2A)**
- Needle tip should be visualized deep to the STSL
- Toggle the transducer to optimize visualization of the needle tip



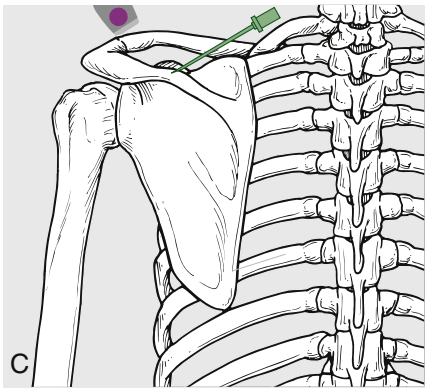


Fig. 34E.2. A, Ultrasound image of out-of-plane needle placement at the level of the suprascapular notch, deep to the superior transverse scapular ligament. **B,** Drawing of relevant structures. Needle is green. Red circle is the suprascapular artery. **C,** Skeleton showing proper ultrasound transducer placement for out-of-plane confirmation.

Out-of-Plane Confirmation Safety Considerations

- Avoid vascular injection by placing the needle tip deep to the STSL into the suprascapular notch **(Fig. 34E.2B)**

Optimal Images (Fig. 34E.3A to C)

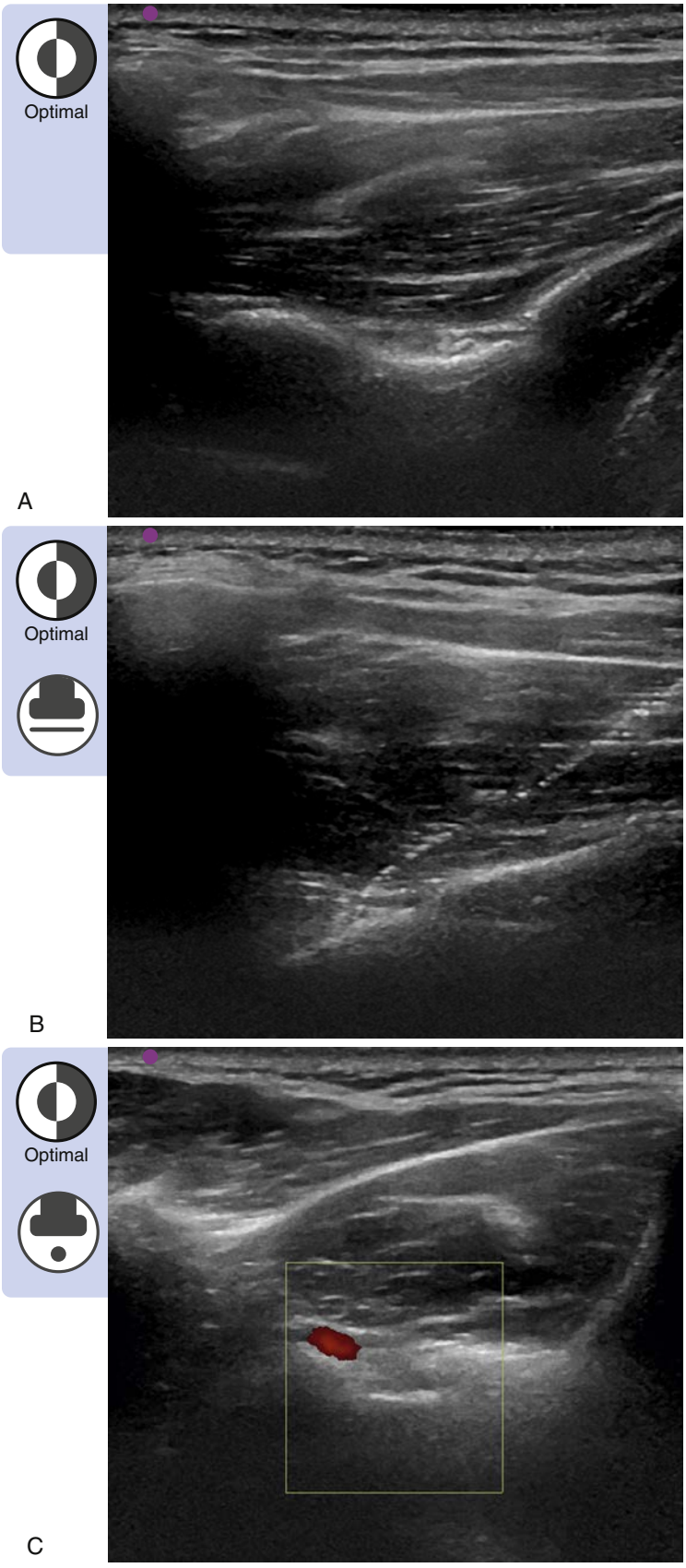


Fig. 34E.3. A, Optimal preneedle placement visualization of the suprascapular notch with the overlying superior transverse scapular ligament with the suprascapular nerve visualized deep to the ligament. **B,** Optimal suprascapular nerve injection showing needle tip in optimal position in the suprascapular notch, deep to the superior transverse scapular ligament. Note the amount of heel-toe maneuvering needed to visualize the needle in-plane. **C,** Optimal needle placement in the suprascapular notch seen in out-of-plane confirmation view. Note the suprascapular artery superficial to the notch.

Suboptimal Images (Fig. 34E.4A,B)

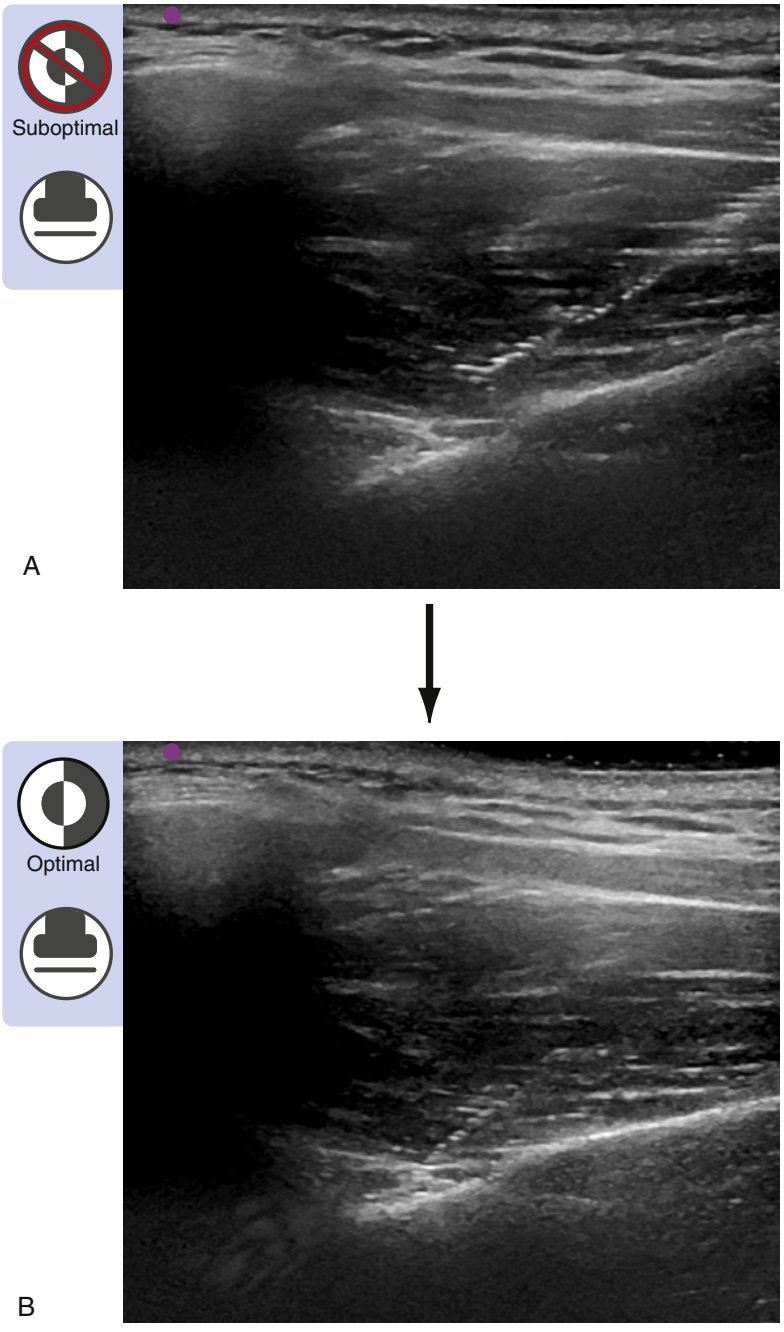


Fig. 34E.4. A and B, Suboptimal needle placement with the needle superficial to the suprascapular notch **(A).** The needle is then repositioned to an optimal location with the needle tip advanced deep to the superior transverse scapular ligament **(B).**

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Sigenthaler A, Moriggl B, Mlekusch S, et al. Ultrasound-guided suprascapular nerve block, description of a novel supraclavicular approach. *Reg Anesth Pain Med*. 2012;37(3):325–328.

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CHAPTER 34F

Biceps Tendon Sheath Injection—In-Plane Approach: Ultrasound Guidance

Stephen C. Johnson, Melinda S. Loveless, and Michael B. Furman

The biceps muscle has two heads, a long head and a short head, which attach to the scapula via individual tendons. Pathology commonly affects the long head, which is generally referred to as the *biceps tendon.* The long head of the biceps originates from the supraglenoid tubercle, labrum, and the joint capsule. It then passes through the triangular space between the tendons of the subscapularis and supraspinatus muscles called the *rotator cuff interval.* Here, the biceps tendon is stabilized by the coracohumeral ligament and superior glenohumeral ligament. As the biceps tendon travels distally it remains in a synovial sheath, shared with the anterior circumflex artery, for approximately 3–4 cm. As the biceps tendon reaches the proximal humerus, it courses through the intertubercular groove (also called the *bicipital groove*) between the greater tuberosity (lateral) and the lesser tuberosity (medial). At this position, it is stabilized in the bicipital groove by the overlying transverse humeral ligament.

Bicipital tenosynovitis is most often secondary to impingement beneath the coracoacromial arch near the bicipital groove but may also occur secondary to instability. Fluid within the sheath is considered abnormal and may occur with localized tenosynovitis. However, the origin of the biceps tendon is intraarticular, thus effusions as a result of intraarticular pathology, such as glenohumeral osteoarthritis or rotator cuff tear, may leak into the biceps tendon sheath.

Biceps tendon sheath injections can be considered for patients with anterior shoulder pain that localizes to the biceps tendon region with accompanying ultrasound findings of tenosynovitis or effusion. This chapter will describe an in-plane technique, short axis to the biceps tendon at the level of the bicipital groove, with out-of-plane confirmation. Safety considerations will also be highlighted, including the use of Doppler imaging to avoid anterior circumflex artery injection.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 34F.1)

- Patient is positioned supine with arm in neutral position with palm up.
- Patient may also be seated with forearm supinated and elbow at 90 degrees of flexion.
- Ultrasound image is on the opposite side of the interventionalist and in line with the transducer (see **Fig. 34F.1A** and Chapter 4).
- Begin by placing the transducer short axis to the biceps tendon at the bicipital groove (axial plane). **(Fig. 34F.1D)**.
- An alternative long-axis (sagittal) approach may also be used by positioning the transducer long axis to the biceps tendon. The short-axis approach is preferred.
- Identify the biceps tendon within its sheath beneath the transverse humeral ligament, in the intertubercular (bicipital) groove between the greater and lesser tuberosities **(Fig. 34F.1A,B)**.
- Toggle the transducer to minimize anisotropy and optimize tendon localization (see Chapter 4).
- With the transducer short axis to the biceps tendon, insert the needle from lateral to medial toward biceps tendon sheath.
- While visualizing the needle tip in plane, advance through the transverse humeral ligament and deep to the tendon sheath but superficial to the tendon **(Fig. 34F.1A,B)**.
- If the needle is superficial to the transverse humeral ligament it may be in the subacromial, subdeltoid bursa.

Fig. 34F.1. A, Room and interventionalist setup for injection.

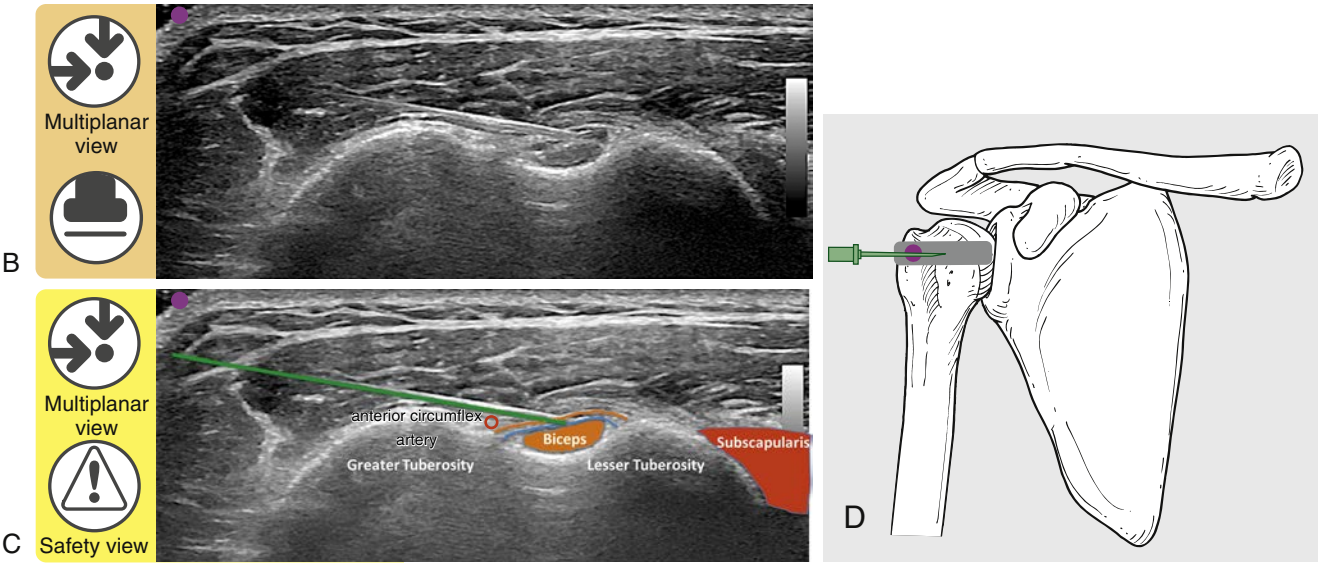

Fig. 34F.1, cont'd B, Ultrasound image of needle placement within the biceps tendon sheath, deep to the transverse humeral ligament, in the bicipital groove formed by the greater and lesser tuberosities. **C,** Drawing of relevant structures. Needle is green. Transverse humeral ligament is in orange. Biceps tendon sheath in blue. Red circle is the anterior circumflex humeral artery. **D,** Skeleton showing proper placement of ultrasound transducer.

In-Plane Technique Safety Considerations

- Use Doppler imaging to avoid vascular injection into the anterior circumflex artery, which lies lateral to the biceps tendon.
- Avoid injection of the tendon itself—be sure to only inject the surrounding sheath—except in certain cases when injecting biologics.

Out-of-Plane Confirmation (Fig. 34F.2)

- After placement deep to the biceps tendon sheath, rotate the transducer 90 degrees to an out-of-plane view to re-confirm that the needle tip is deep to the tendon sheath and superficial to this long-axis view of the biceps tendon **(Figs. 34F.2A** to **C).**

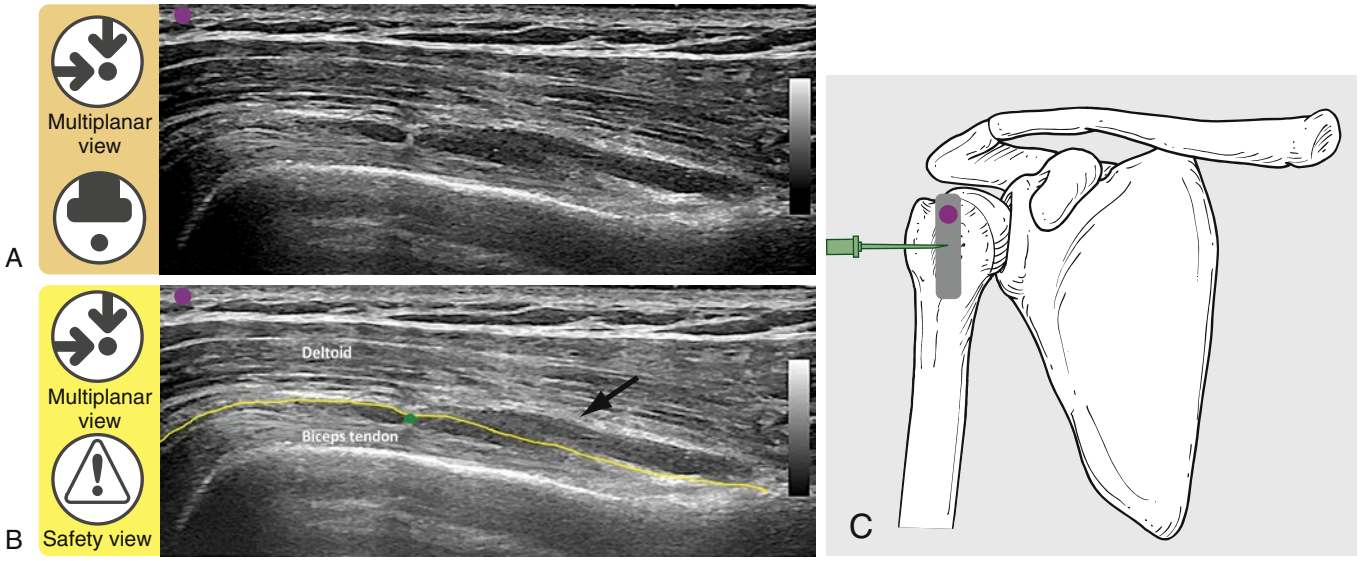

Fig. 34F.2. A, Ultrasound image of out-of-plane needle placement in the dorsal aspect of the biceps tendon sheath. **B,** Drawing of relevant structures. Needle is green. Biceps tendon sheath in yellow. In this image, some of the injectate is also visualized in the subacromial, subdeltoid bursa superficial to the tendon sheath (black arrow). **C,** Skeleton showing proper placement of ultrasound transducer for out-of-plane confirmation.

Out-of-Plane Technique Safety Considerations

- Avoid injection of the biceps tendon.
- Spread of injectate should be visualized circumferentially around the tendon and within the sheath.

Optimal Images (Fig. 34F.3A,B)

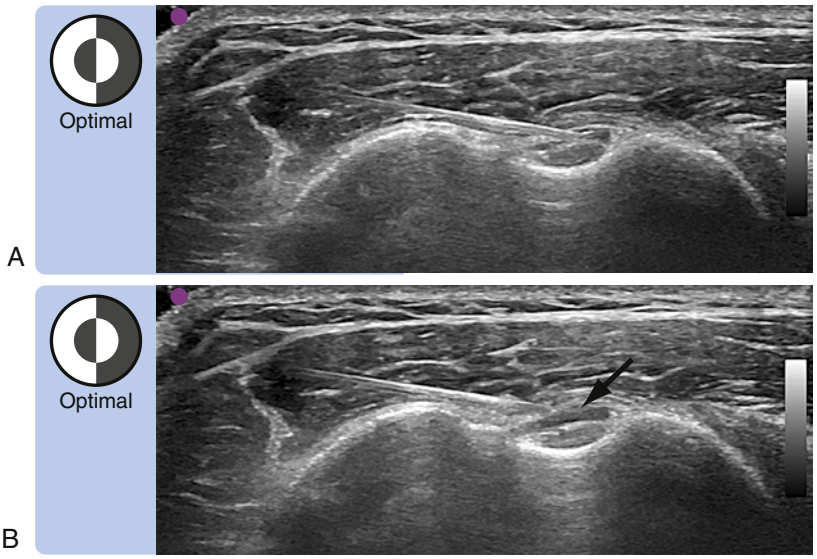

Fig. 34F.3. A, Optimal needle placement within the biceps tendon sheath using an in-plane, short-axis approach. **B,** Optimal needle placement. Injectate is seen filling the biceps tendon sheath causing the transverse humeral ligament to distend.

Suboptimal Images (Fig. 34F.4 and Fig. 34F.5)

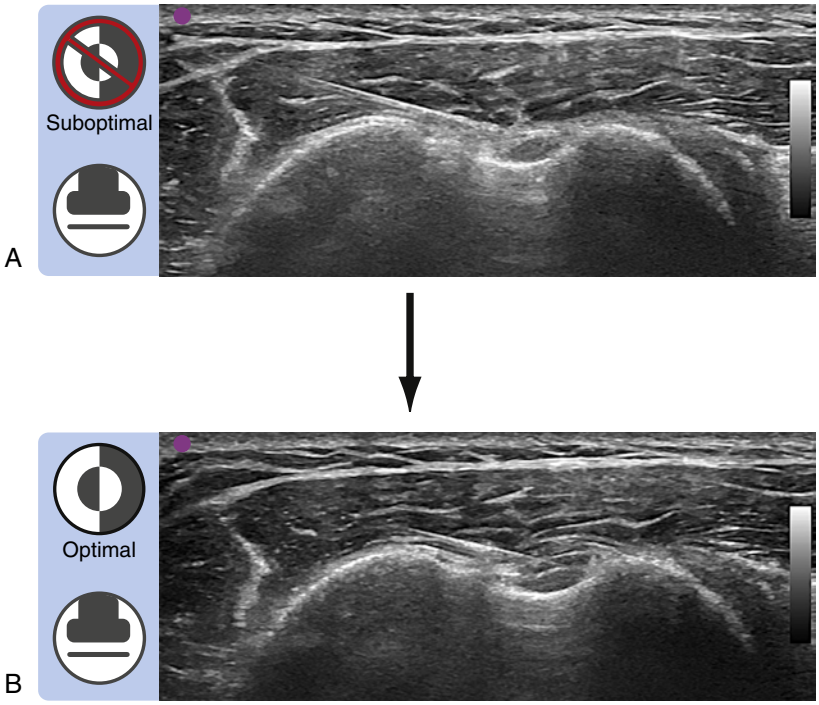

Fig. 34F.4. A, Suboptimal needle placement with the needle superficial to the biceps tendon sheath. **B,** The needle is then advanced to an optimal location deep to the transverse humeral ligament and within the biceps tendon sheath.

Fig. 34F.5. Suboptimal needle placement using the alternative, long-axis approach with the needle tip superficial to the biceps tendon sheath within the subacromial, subdeltoid bursa. Injectate is seen filling the bursa and not the tendon sheath. The needle tip should be advanced slightly until within the sheath.

Suggested Readings

Jacobson J. *Fundamentals of Musculoskeletal Ultrasound*. Philadelphia, PA: Saunders; 2007.

Patton WC, McClusky GM III. Biceps tendinitis and subluxation. *Clin Sports Med*. 2001;20(3):505–529.

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Hip Region Injections

CHAPTER 35

Hip disorders often masquerade as lumbar pathology. Patients with hip issues may present with similar complaints as those with lumbar radiculopathy. It is important to consider the femoro-acetabular joint, the myriad of bursae around the gluteal tendons and greater trochanter, and the lateral femoral cutaneous nerve as pain generators in the differential diagnosis of patients presenting with back or "hip" pain. Likewise, lumbar radiculopathy or lumbar Z-joint pain can often manifest as pain in the hip or buttock region, including the anterior, lateral, and posterior thigh as well as the groin.

The hip joint is subject to arthritides, impingement, and trauma. Patients with intraarticular hip pathology typically present with groin and/or buttock pain exacerbated by weight-bearing activities, often similar to pathology affecting the L2 or L3 nerve roots. Greater trochanteric pain syndrome (GTPS), known as the "Great Mimicker" of sciatica, can cause pain in the lateral hip and thigh. Meralgia paresthetica, a lateral femoral cutaneous nerve mononeuropathy (LFCN), presents with painful paresthesias and numbness in the superior anterolateral thigh.

History and physical exam can help differentiate hip from lumbar pathology. Concordant pain elicited on palpation of the groin or over the greater trochanter may indicate an intraarticular or bursal source, respectively. In addition, concordant pain may be elicited upon passive rotation maneuvers including the Flexion, ABduction, External Rotation (FABER-Patrick's) and Flexion, ADduction, Internal Rotation-impingement tests or active maneuvers such as the Stinchfield (resisted hip flexion) test.

In this chapter, we will review both fluoroscopic and ultrasound techniques for guided access into these hip region structures.

Suggested Readings

Aszmann OC, Dellon ES, Dellon LA, Dellon. Anatomical course of the lateral femoral cutaneous nerve and its susceptibility to compression and injury. *Plast Reconstr Surg*. 1997;100(3):600–604.

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3. Khan AM, McLouglin E, Giannakas K, Hutchinson C, Andrew JG. Hip osteoarthritis: where is the pain? *Ann R Coll Surg Engl*. 2004;86(2):119–121.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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CHAPTER 35A

Intraarticular Hip Injection—Anterior Approach: Fluoroscopic Guidance

Simon J. Shapiro, Jonathan S. Kirschner, and Michael B. Furman

Intraarticular hip injection can be used for both diagnosing and treating pain emanating from the femoro-acetabular joint. It can also be used to deliver contrast prior to a magnetic resonance (MR) arthrogram.

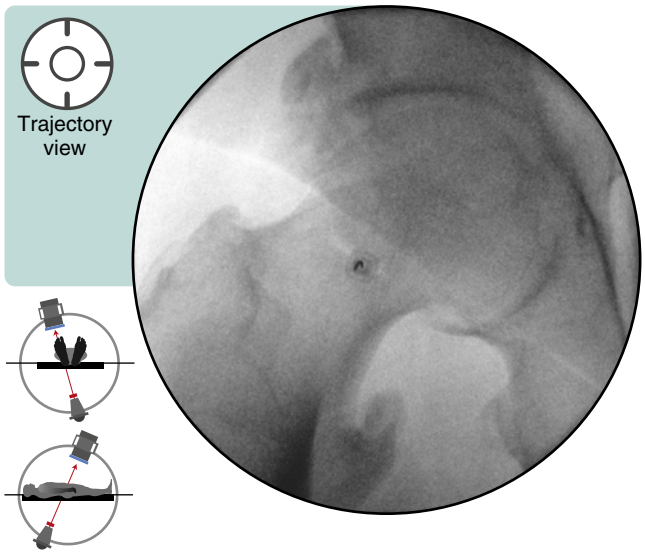
In this chapter, we describe an anterior approach with the patient in a supine position. This can be beneficial when performing bilateral hip injections and is sometimes the preferred position of comfort for the patient. Primary safety considerations include avoiding the femoral nerve, artery, and vein, which lie anterior to the medial aspect of the femoro-acetabular joint. Additionally, branches of the lateral circumflex femoral artery course along the anterior intertrochanteric line and femoral neck, some of which anastomose with the medial circumflex femoral artery, therefore, contributing blood supply to the femoral neck and head. Theoretically, occlusion of these vessels could cause avascular necrosis.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

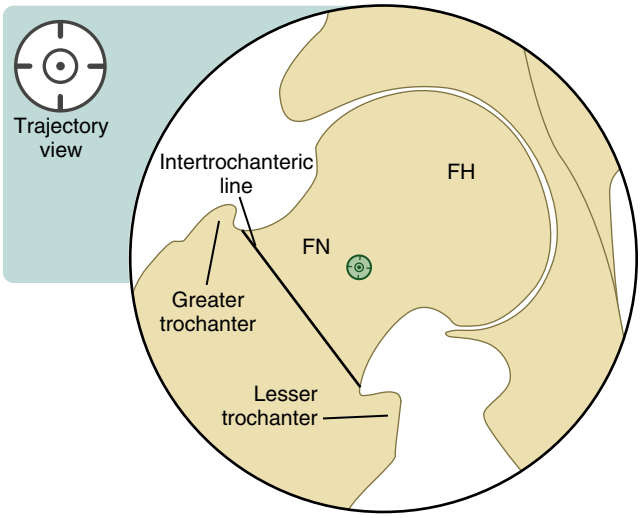
Trajectory View (Fig. 35A.1)

- Place the patient in the supine position.
- Position the C-arm over the target hip joint.
- **Tilt the C-arm caudally and oblique medially or laterally** to obtain the trajectory view so that the **needle entry is inferior to the inguinal crease,** with the needle entering the proximal thigh and not the abdomen (see Fig. 35A.1).
- The target is approximately at the midline of the anterior femoral head–neck junction.
- The needle is placed parallel to the fluoroscopic beam.

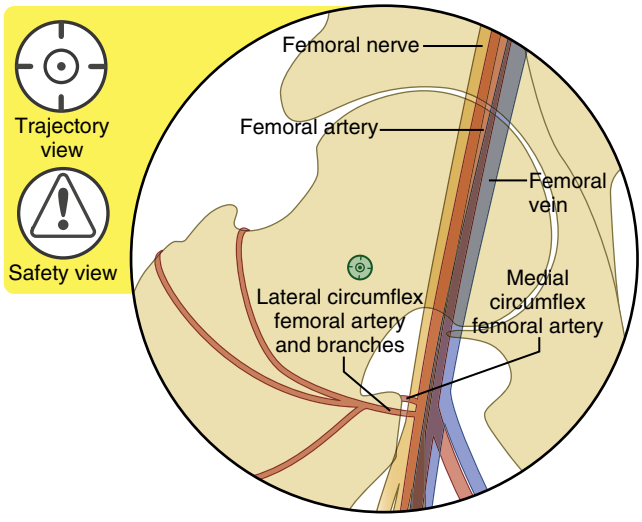
The Trajectory View Is Also a Multiplanar View



A



B



C

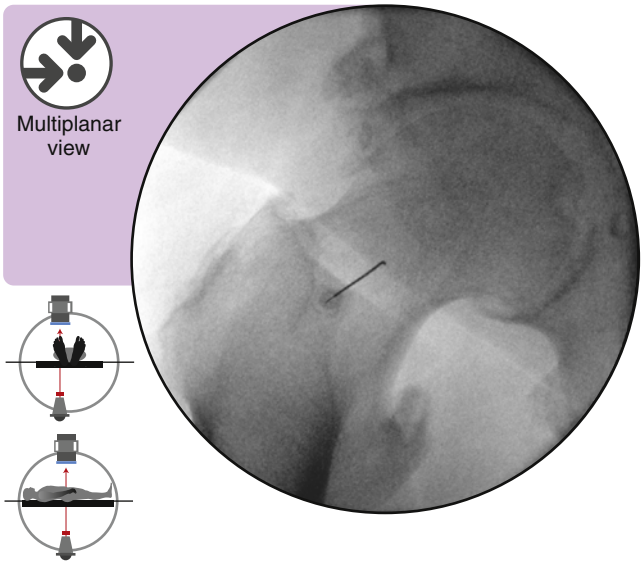
Trajectory View Safety Considerations (Fig. 35A.1C)

- **Stay clear of the medial aspect of the joint**, where the neurovascular bundle lies (lateral to medial: femoral nerve, artery, and vein).
- Vascularization of the anterior femoral head–neck junction is variable.
- **Avoid vascular injection** by checking for negative aspiration and careful observation of the contrast flow under live fluoroscopy. Consider digital subtraction if needed.

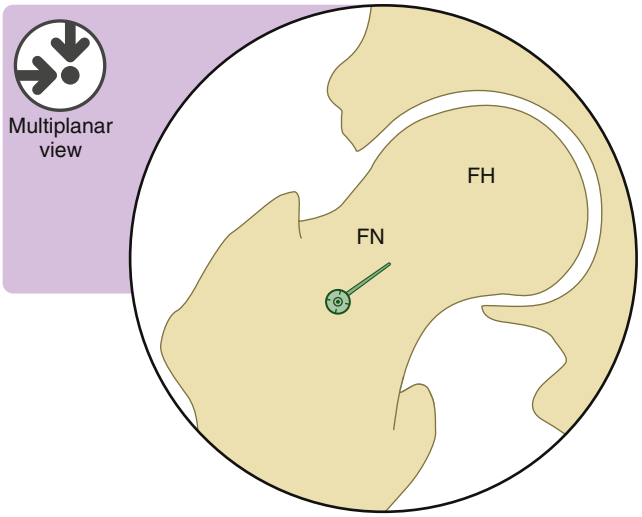
Fig. 35A.1. A, Fluoroscopic image of the trajectory view. **B,** Radiopaque structures, trajectory view. *FH,* Femoral head; *FN,* femoral neck. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging (Fig. 35A.2)

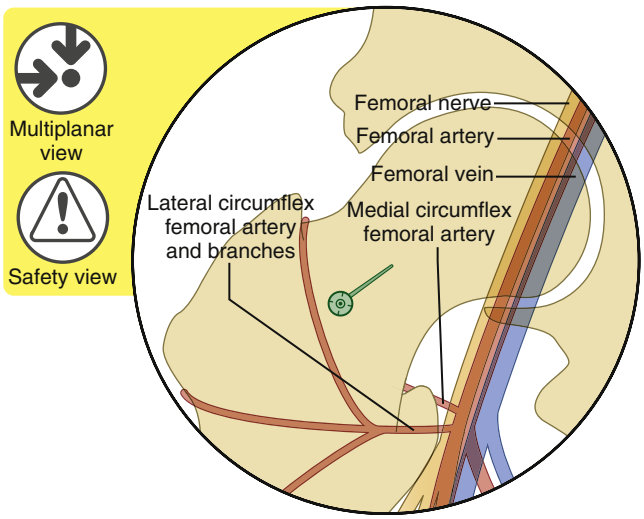
- Multiplanar imaging is recommended. This may be obtained before or after penetration of the joint capsule.
- After placing the needle and advancing toward the target in the trajectory view, position the C-arm to approximate an posteroanterior (PA) view of the target joint.
- If needed, the needle is further advanced to penetrate the joint capsule and contact the periosteum at the femoral head–neck junction (see Fig. 35A.2).
- After gentle contact with periosteum, contrast can be placed. A minimal amount is needed.
  - If there is resistance, the bevel may be buried in the periosteum or the redundant hip capsule. In this case, withdraw the needle 1 to 2 mm and again inject a small amount of contrast.
- The joint capsule extends from the femoral neck up around the femoral head. It reflects upon itself distally. See Fig. 35A.3A,B, which shows an MR arthrogram of the right hip. Note the extent of the joint capsule when distended.



A



B



C

Fig. 35A.2. A, Fluoroscopic image of the posteroanterior (PA) view. **B,** Radiopaque structures, PA view. *FH,* Femoral head; *FN,* femoral neck. **C,** Radiolucent structures, PA view.

Anteroposterior View Safety Considerations

- **Stay clear of the medial aspect of the joint**, where the neurovascular bundle lies (lateral to medial: femoral nerve, artery, and vein).
- Vasculature at the anterior femoral head–neck junction is variable, predominantly from cervical branches of the ascending branch of the lateral circumflex femoral artery, and some branches may anastomose with the medial circumflex femoral artery, thus, contributing blood supply to the femoral neck and head. Theoretically, occlusion of these vessels could cause avascular necrosis.
- **Avoid vascular injection** by checking for negative aspiration and careful observation of the contrast flow under live fluoroscopy. Consider digital subtraction if needed.
- Take care not to penetrate periosteum, especially in cases of known osteoporosis.

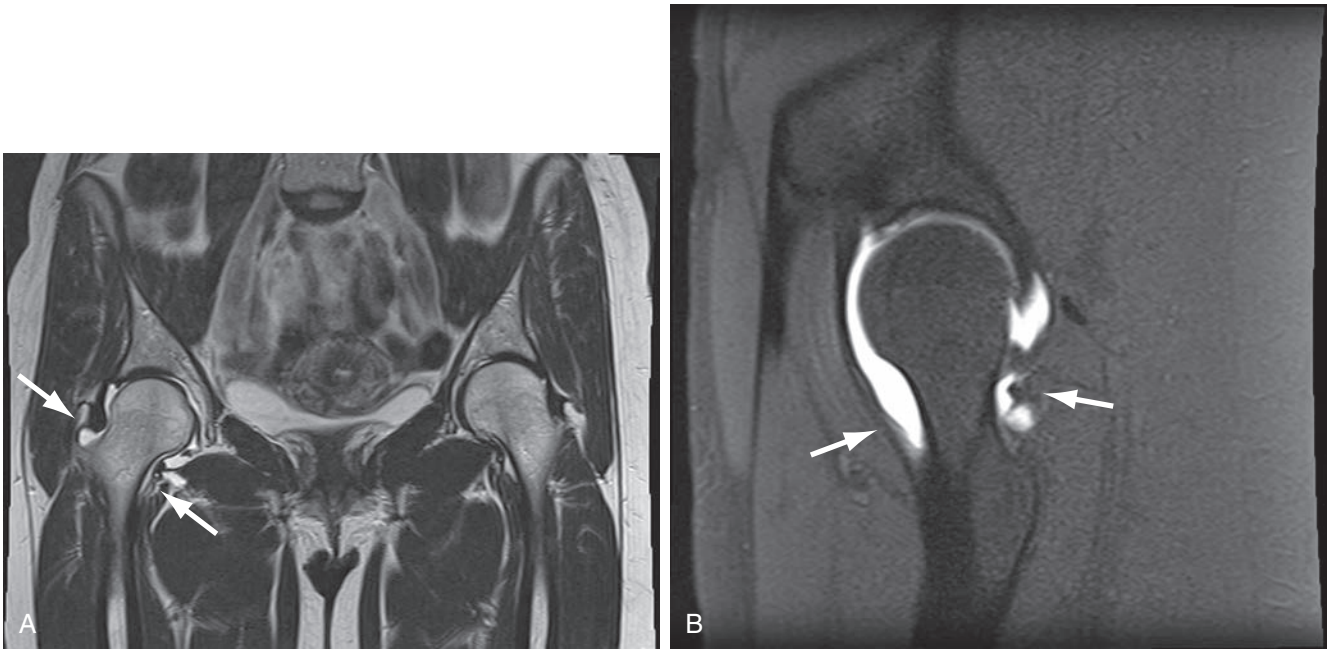


Fig. 35A.3. Magnetic resonance arthrogram of the right hip. Note the extent of the joint capsule when distended (arrows). **A,** Coronal view. **B,** Sagittal view (anterior aspect to the left). Note how the capsule (arrows) reflects upon itself on the surface of the femoral neck.

Optimal Images (Fig. 35A.4)

Ideal intraarticular contrast flow is subcapsular and typically wraps around the femoral neck toward the inferomedial aspect of the femoral head and joint space. If a washout view is taken, the contrast is found in the inferior recess. In some patients, the contrast can extravasate to the iliopsoas or greater trochanteric bursa.

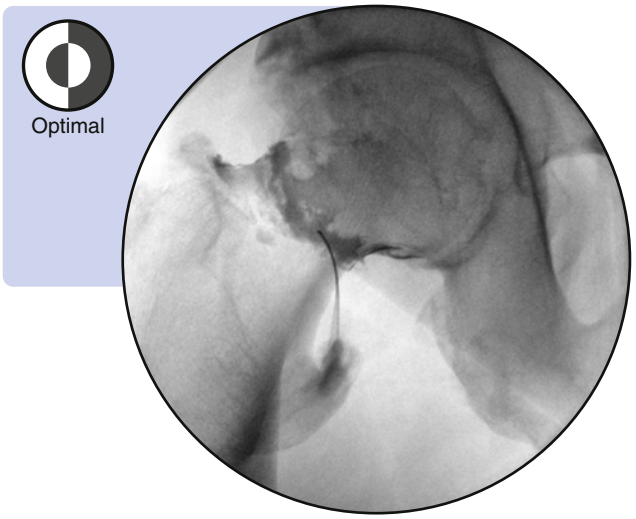


Fig. 35A.4. Optimal contrast flow.

Suboptimal Images (Figs. 35A.5 and 35A.6)

The streaky vertical parallel lines suggest an intracapsular injection (*open arrow*). Also, there is vascular flow (*closed arrow*); note the fine reticular pattern. If non-vascular flow cannot be obtained, we suggest avoiding particulate steroids.

The intertrochanteric line typically represents the distal extent of the hip capsule. Therefore, the needle tip should ideally touch periosteum proximal to the intertrochanteric line if intraarticular flow is desired.

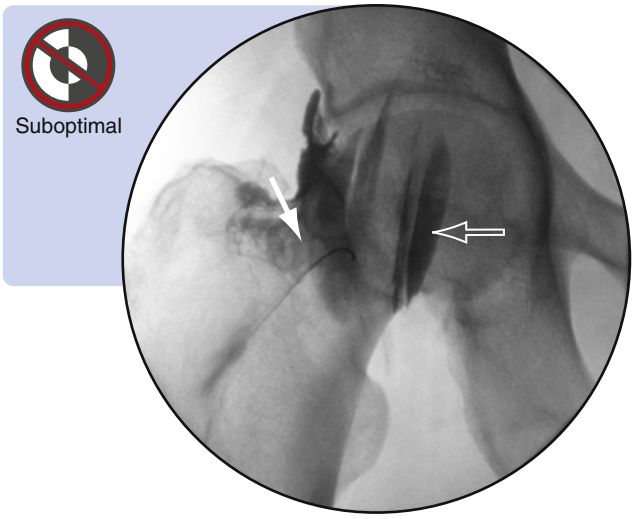


Fig. 35A.5. Suboptimal flow. There is a subtle fine vascular flow (closed arrow); also, note the suboptimal intracapsular flow (open arrow) implied by a streaked pattern.

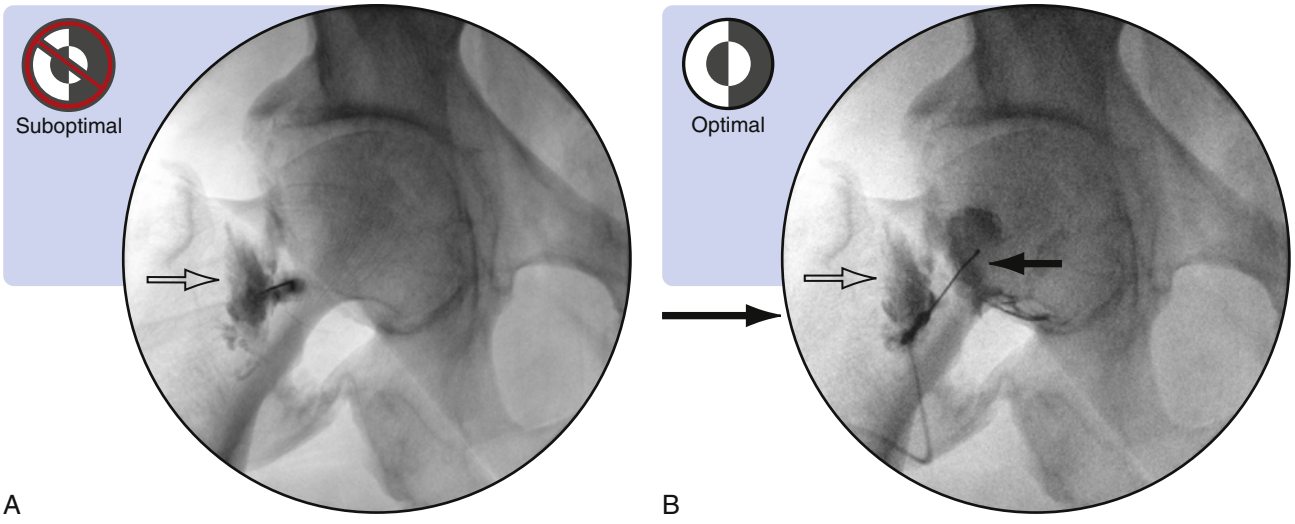


Fig. 35A.6. A, Initially, the needle is positioned too far inferiorly on the femoral neck, and there is suboptimal flow. The initial pattern was extracapsular (open arrow). **B,** After repositioning the needle superiorly toward the femoral head–neck junction, proximal to the intertrochanteric line, an optimal subcapsular intraarticular flow pattern is achieved (closed arrow).

CHAPTER 35B

Intraarticular Hip Injection—Lateral Approach: Fluoroscopic Guidance

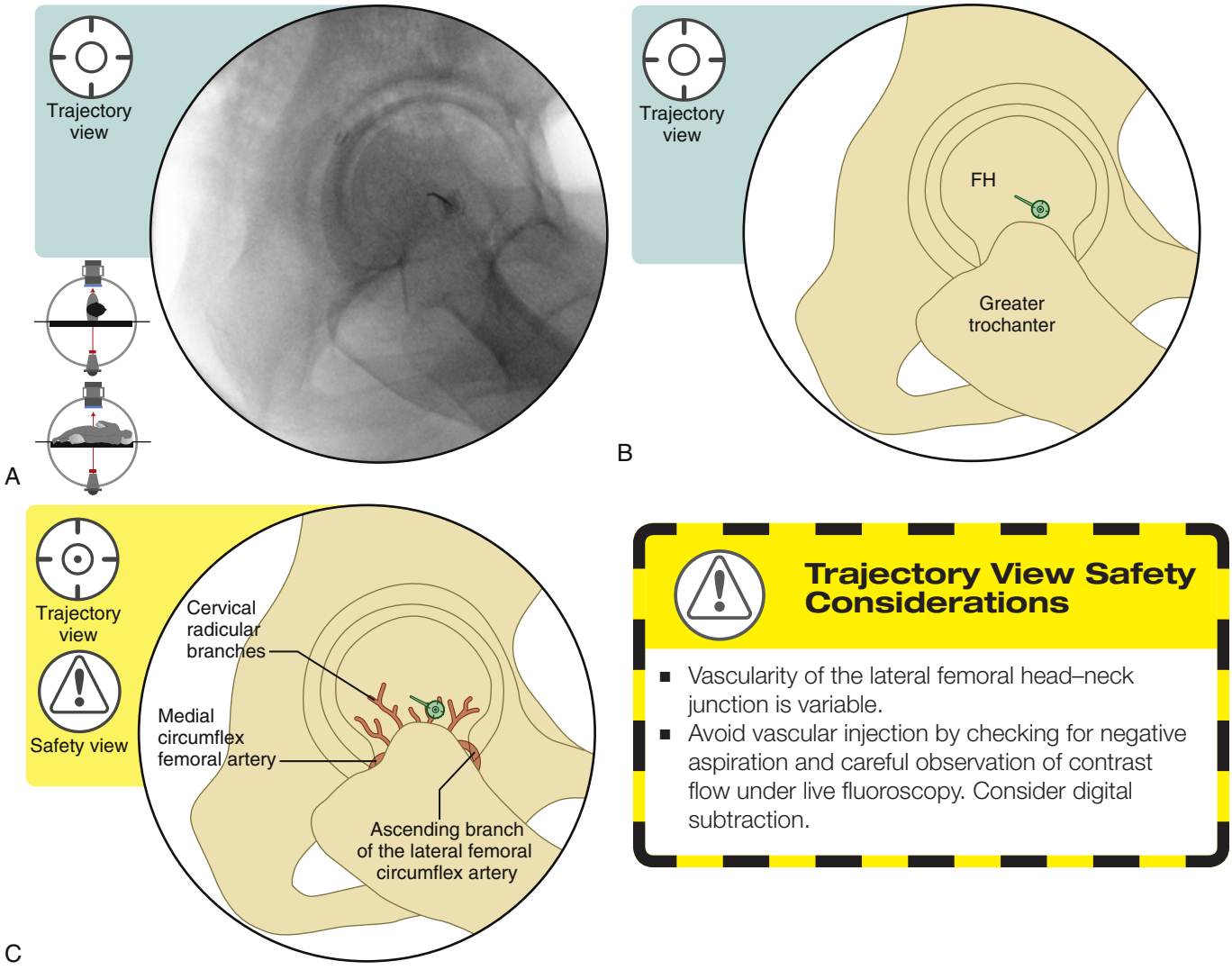
Simon J. Shapiro, James J. Gilhool, and Michael B. Furman

The hip joint can be safely and effectively accessed via a lateral approach, which has its own merits and presents a path to the joint with minimal anatomic variation or radiolucent dangers. A lateral approach may be favored in patients who have a large abdominal abundance, skin infection near the groin region, an inability to tolerate supine positioning, and/or cultural reasons related to patient modesty.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 35B.1)

- Place the patient in the lateral recumbent position, with the target hip joint facing up (away from the table).
- Obtain a lateral view of the hip joint.
- **Tilt and oblique the C-arm to line up the femoral heads** to obtain (or at least approximate) a "bull's eye" view (see Fig. 35B.1). The smaller, target femoral head fits nicely inside the contralateral femoral head.
  - The smaller head (the target) is closer to the image intensifier. The non-targeted contralateral head is magnified (as described in Chapter 3) because it is farther from the image intensifier (and closer to the image source).
- **The target is the femoral head–neck junction**, which corresponds on the trajectory view to the center of the "upside" femoral head as seen on the lateral view.
- Be sure the needle trajectory is superior to the greater trochanter because it can block joint access.
- The needle is placed parallel to the fluoroscopic beam, further accentuating the "bull's eye" pattern (see Fig. 35B.1A to C).
- Advance the needle toward the target, staying near the midline between the anterior and posterior silhouettes of the femoral head, and superior to the greater trochanter.



Trajectory View Safety Considerations

- Vascularity of the lateral femoral head–neck junction is variable.
- Avoid vascular injection by checking for negative aspiration and careful observation of contrast flow under live fluoroscopy. Consider digital subtraction.

Fig. 35B.1. A, Fluoroscopic image of the trajectory view with bilateral femoral heads superimposed. **B,** Radiopaque structures, trajectory view. *FH,* Femoral head. **C,** Radiolucent structures, trajectory view. The smaller head (the target) is closer to the image intensifier. The non-targeted contralateral head is magnified because it is farther from the image intensifier (and closer to the image source).

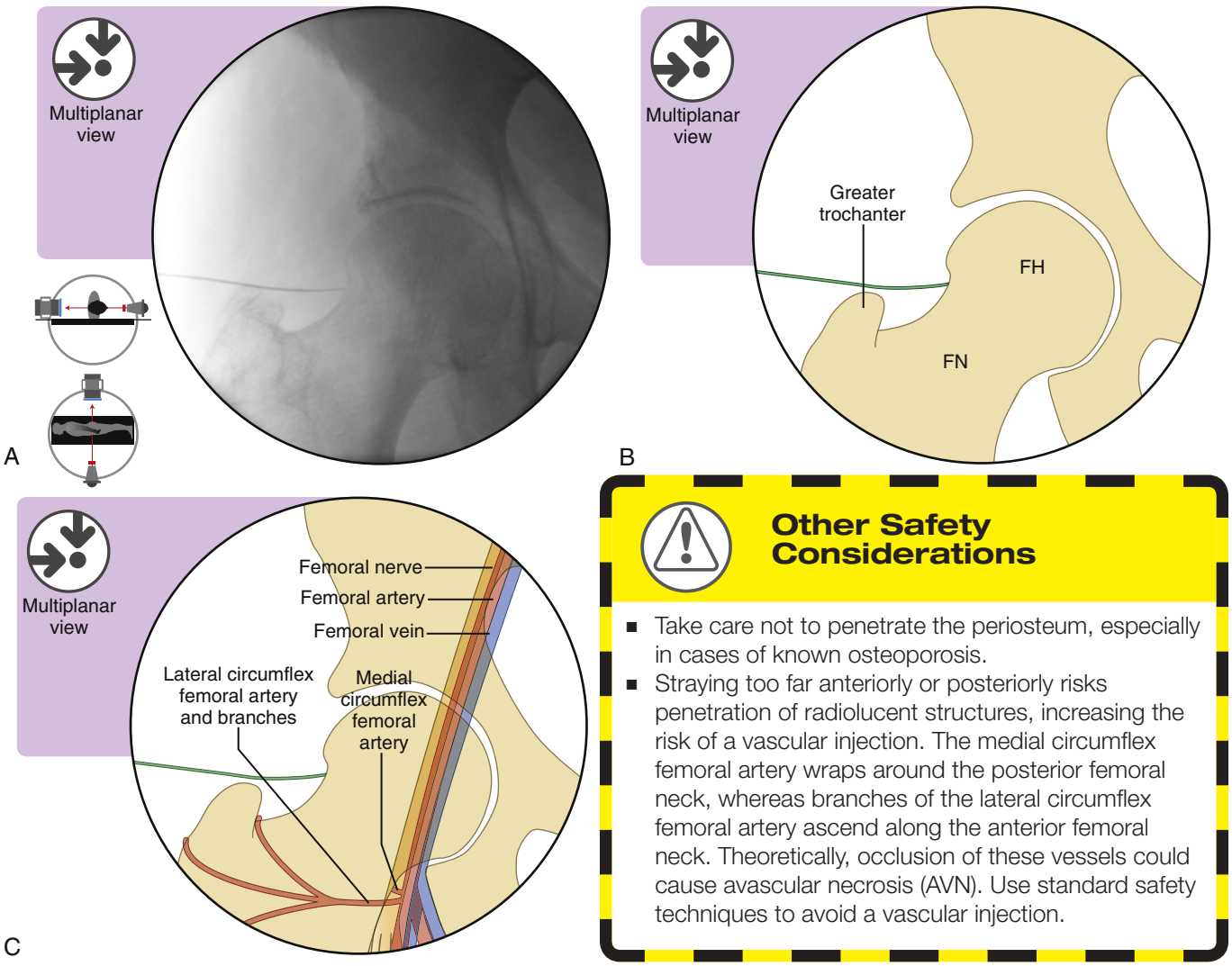
The Trajectory View Is Also a Multiplanar View

Notes on Positioning in the Trajectory View

- The “bull’s eye” view need not be perfect. Even slight patient movements will affect the pattern seen on fluoroscopy.
- The important thing is that **both femoral heads are seen and differentiated so that the smaller femoral head target is clear.**
- Due to magnification (as noted in Chapter 3):
  - The femoral head closer to the image intensifier (further from the beam source) will appear smaller.
  - The femoral head farther from the image intensifier (and closer to the beam source) will appear larger.
- With the beam source under the table and the image intensifier over the table, **the smaller-appearing femoral head is the target.**
- Placement of the needle too far caudally runs the risk of encountering the superior aspect of the greater trochanter, preventing further advancement toward the target. A good rule of thumb is to target halfway between the superior aspect of the greater trochanter and the cephalad silhouette of the ipsilateral femoral head as seen on the lateral image.

Optimal Needle Position in Multiplanar Imaging (Fig. 35B.2)

- After placing the needle and advancing toward the target in the trajectory view, **position the C-arm to obtain an anteroposterior (AP) view of the target joint** (relative to the patient). This is horizontal to the floor.
- Ideally, switch to the AP view prior to contacting periosteum. This will allow for slight course corrections that may be needed for optimal placement at the femoral head–neck junction.
- In the AP view, it is now apparent that what appeared to be the center of the femoral head is actually the junction of the head with the neck of the femur, which is the true target.
- The needle is further advanced, with the bevel caudal or cephalad only, to contact the periosteum at the femoral head–neck junction.
- In order to avoid anterior or posterior drift off target while advancing in the AP view, **advance the needle with the bevel caudal or cephalad only.** Do not advance the needle with the bevel anterior or posterior while in the AP view.
- Advance the needle until contact is made at the femoral head–neck junction.
- After gentle contact with the periosteum, contrast can be placed. A minimal amount is needed.
  - If there is resistance, the bevel may be buried in the periosteum or the capsule. In this case, withdraw the needle 1 to 2 mm and again inject a small amount of contrast.
- The joint capsule extends from the femoral neck up around the femoral head. See Fig. 35A.3, which shows a magnetic resonance arthrogram of the right hip. Note the extent of the joint capsule when distended.



Other Safety Considerations

- Take care not to penetrate the periosteum, especially in cases of known osteoporosis.
- Straying too far anteriorly or posteriorly risks penetration of radiolucent structures, increasing the risk of a vascular injection. The medial circumflex femoral artery wraps around the posterior femoral neck, whereas branches of the lateral circumflex femoral artery ascend along the anterior femoral neck. Theoretically, occlusion of these vessels could cause avascular necrosis (AVN). Use standard safety techniques to avoid a vascular injection.

Fig. 35B.2. A, Fluoroscopic image of the anteroposterior (AP) view. **B,** Radiopaque structures, AP view. *FH,* Femoral head; *FN,* femoral neck. **C,** Radiolucent structures, AP view.

Optimal Images (Figs. 35B.3 and 35B.4)

Ideal contrast flow should be intracapsular and typically wraps around the neck toward the inferomedial aspect of the femoral head and joint space. If a washout view is taken, the contrast is found in the inferior recess.

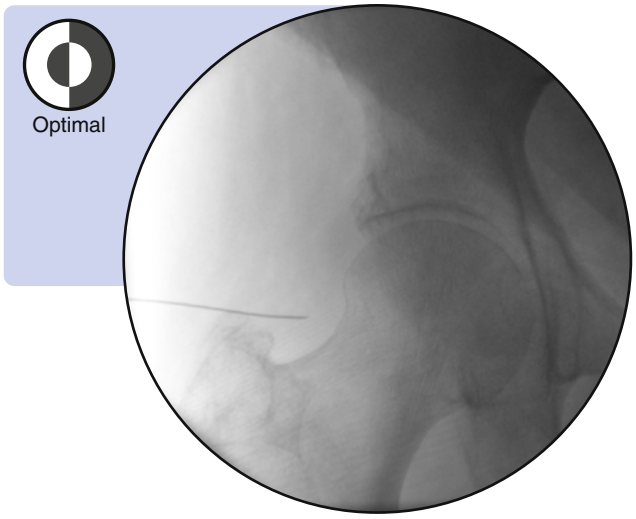


Fig. 35B.3. The needle was placed and partially advanced in the trajectory view before spinning the C-arm to obtain this anteroposterior view of the needle approaching the target. The needle can now be directed slightly cephalad toward the femoral head–neck junction.

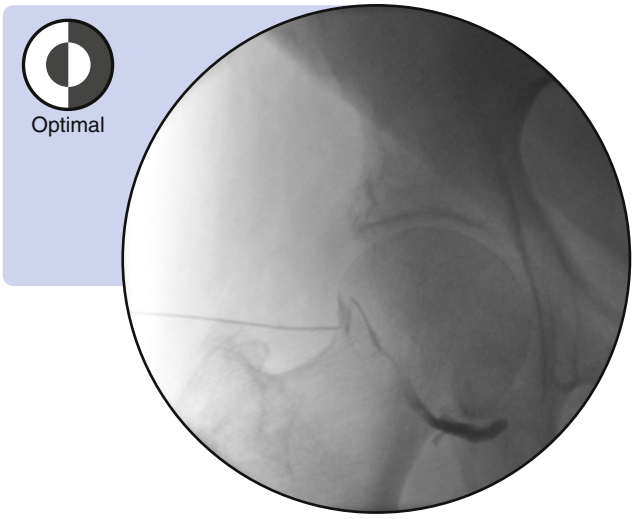


Fig. 35B.4. The needle has been advanced to the femoral head–neck junction, and contrast has been placed. The contrast wraps around the femoral neck within the capsule to the inferomedial aspect of the femoral head.

CHAPTER 35C

Intraarticular Hip Injection—Anterior Approach: Ultrasound Guidance

Justin D. Waltrous, Shounuck I. Patel, Paul S. Lin, and Michael B. Furman

Ultrasound can be used to identify and aspirate joint effusions as well as ensure the needle is not embedded within the redundant hip capsule. Ultrasound also allows for the direct visualization of capsular distention as the injectate enters the joint space. An in-plane technique with out-of-plane confirmation will be described. Live fluoroscopy with contrast visualization should be considered to avoid vascular uptake.

In this chapter, we describe an anterior approach with the patient in a supine position. Primary safety considerations include avoiding the femoral nerve, artery, and vein, which lie anterior to the medial aspect of the femoro-acetabular joint. Additionally, branches of the lateral circumflex femoral artery course along the anterior intertrochanteric line and femoral neck, some of which anastomose with the medial circumflex femoral artery, therefore, contributing blood supply to the femoral neck and head. Theoretically, occlusion of these vessels could cause avascular necrosis.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 35C.1)

- Supine patient.
- Interventionalist on patient's ipsilateral side (Fig. 35C.1A).
- Ultrasound image contralateral to the interventionalist and in line with transducer (see Fig. 35C.1A and Chapter 4).
- Identify the femoral artery and vein in a short axis view.
- **Begin distally** with femur in short axis, **track proximally** to the femoral neck.
- **Translate medially** to the head–neck junction.
- **Rotate transducer** (initially toward the umbilicus) to optimize the capsule's anterior recess, directly superior to the femoral head–neck junction (Fig. 35C.1B,C,D).
- **Consider internally and externally rotating thigh** passively relative to the acetabulum to confirm the location and to identify effusions if present.
- With the transducer still in the long axis to the femoral neck and head, insert needle from an **inferolateral to superomedial direction** toward the femoral head–neck junction.
- While visualizing the needle tip in a long axis view, advance until the needle tip is **advanced through the capsule (Fig. 35C.1B,C)**.

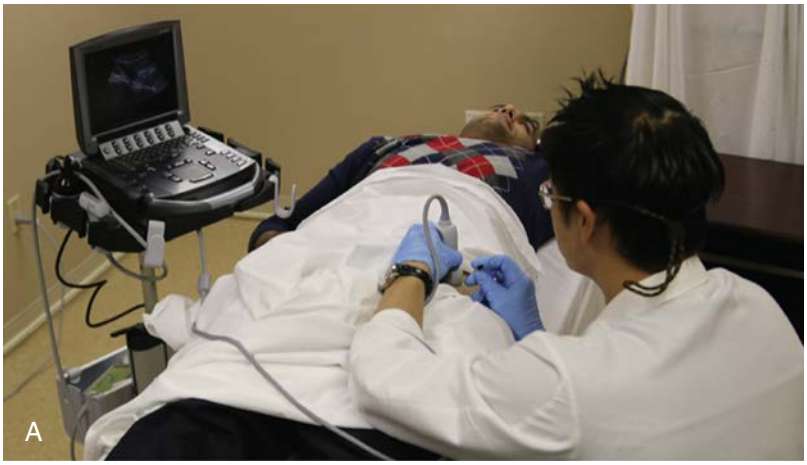


Fig. 35C.1. A, Room, interventionalist, transducer, and US unit setup for intraarticular hip injection.

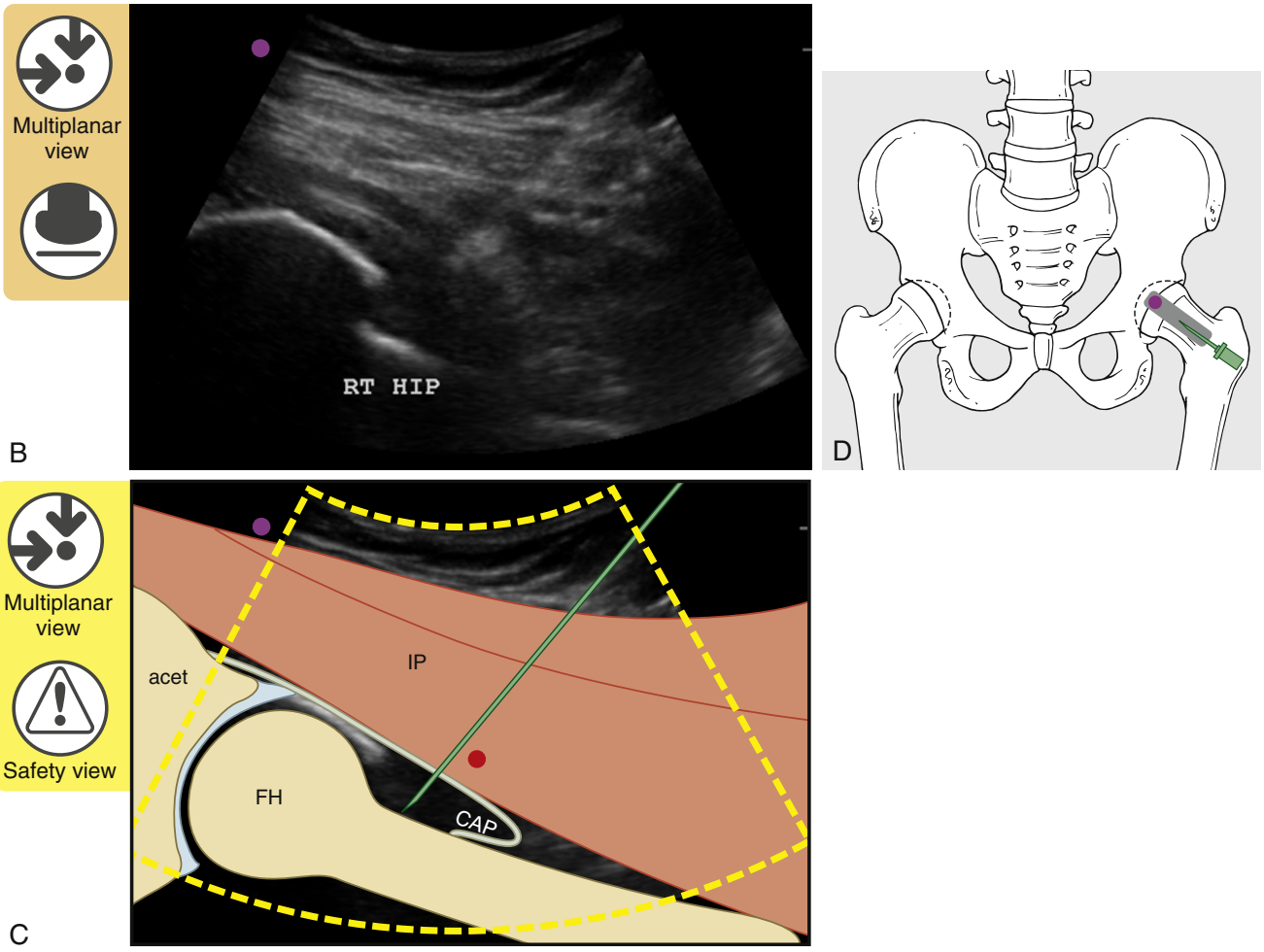


Fig. 35C.1 cont'd Ultrasound (US) image of in-plane hip joint injection. **B,** US image. **C,** Drawing of relevant structures. Yellow dashed outline represents borders of image seen on US image 35C.1B. Red circle represents simulated circumflex artery; *Acet,* Acetabulum; *IP,* iliopsoas; *FH,* femoral head; *CAP,* capsule. **D,** Proper placement of US transducer.

In-Plane Technique Safety Considerations

- Identify the presence of any artery, including the circumflex artery so it can be avoided.
- If too medial, the needle can contact the femoral neurovascular structures.

Out-of-Plane Confirmation (Fig. 35C.2A,B)

- After intraarticular placement with in-plane technique, rotate the transducer 90 degrees to an out-of-plane view to re-confirm subcapsular needle tip position.
- If the needle tip is well placed deep to the capsule, it should not be difficult to rotate the transducer to locate the tip as migration is unlikely.
- For an obese patient with a large pannus, as an alternate approach, you can insert the needle out-of-plane while viewing the joint in short axis.

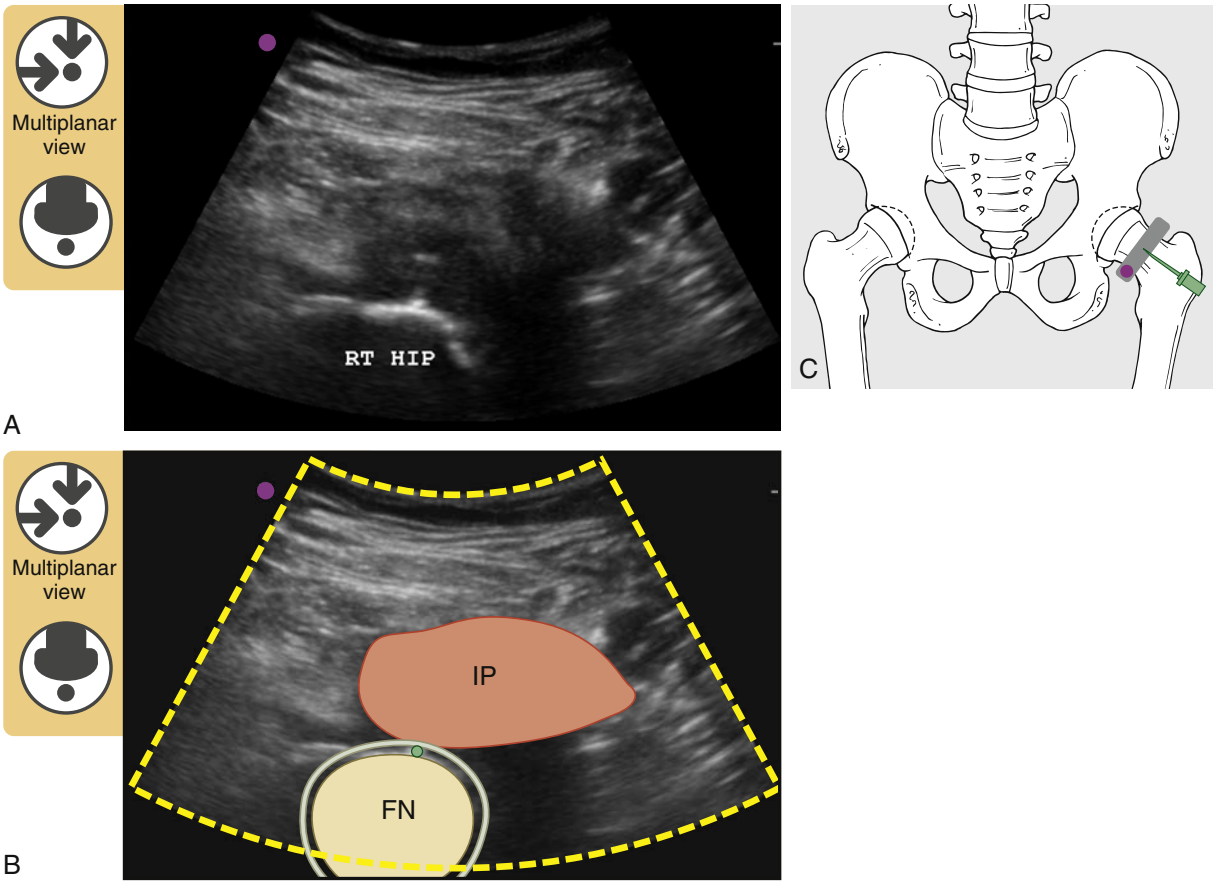


Fig. 35C.2. Ultrasound (US) image of out-of-plane hip joint injection. **A,** US image of intraarticular hip needle placement on femoral head–neck junction. **B,** Drawing of relevant structures. Yellow dashed outline represents borders of the image seen on US image 35C.2A. *FN,* Femoral neck in short axis. **C,** Proper placement of US transducer for out-of-plane confirmation.

Out-of-Plane Technique Safety Considerations

- Avoid the medially located neurovascular structures (not shown).
- This out-of-plane view is ideal for identifying proximity to the medial neurovascular structures.

Optimal Image (Fig. 35C.3)

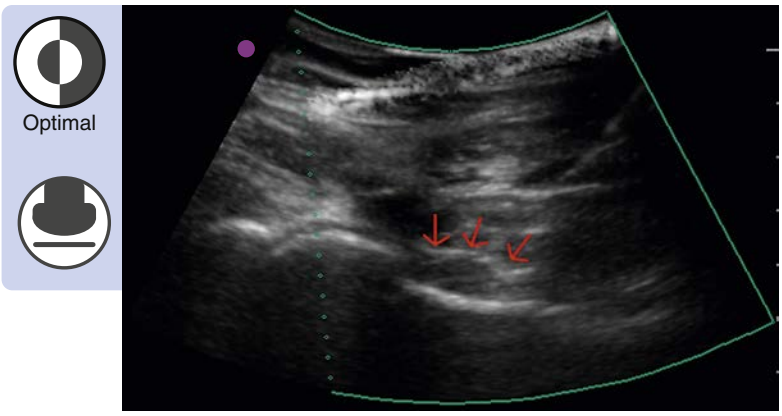


Fig. 35C.3. Optimal intraarticular injection showing capsular distention (red arrows).

Suboptimal Images (Fig. 35C.4)

- Avoid a vascular injection into the circumflex artery to decrease the risk of an injection-related avascular necrosis.
- Avoid contact with the medial neurovascular structures.

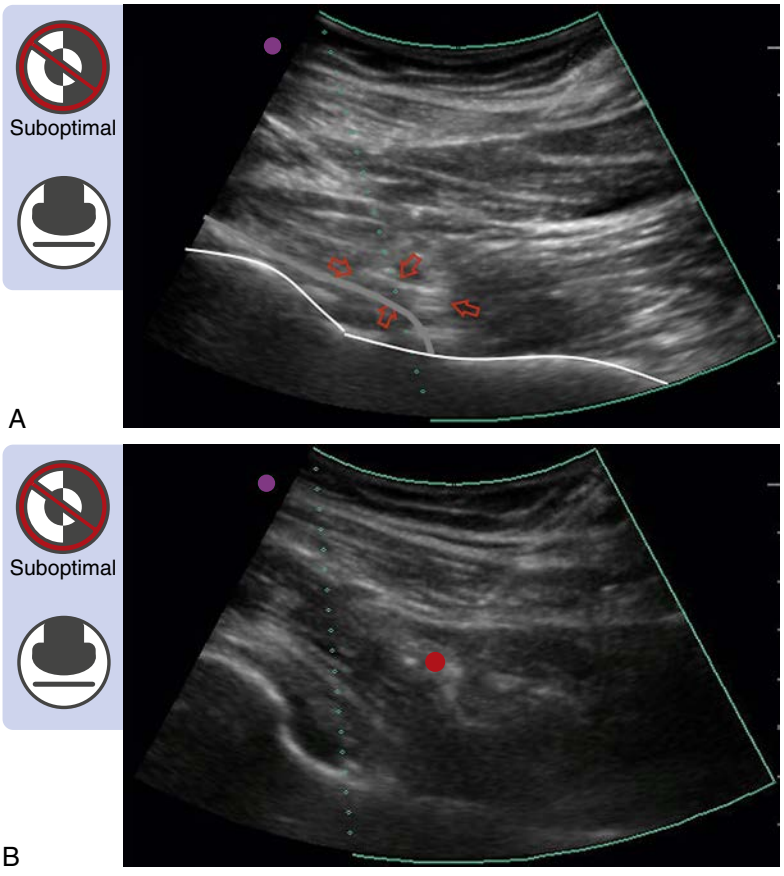


Fig. 35C.4. A, Extracapsular injection (red open arrows). **B,** Simulation of needle piercing the circumflex artery (red circle).

Suggested Readings

Hoeber S, Aly AR, Ashworth N, Rajasekaran S. Ultrasound-guided hip joint injections are more accurate than landmark-guided injections: a systematic review and meta-analysis. *Br J Sports Med*. 2016;50(7):392–396.

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CHAPTER 35D

Greater Trochanteric Bursa/Gluteus Medius Injection: Ultrasound Guidance

Jackson Liu, Naimish Baxi, Jonathan S. Kirschner, and Michael B. Furman

Greater trochanteric pain syndrome (GTPS), known as the *Masquerader,* can often be mistaken for other hip or lumbar pathologies. GTPS presents with pain over the lateral hip, with possible radiation into the lateral thigh. Several muscles insert at or near the greater trochanter of the femur, which is composed of tendon attachment points including the superoposterior, lateral, and anterior facets. There are three main bursae that can be a source of pain: the subgluteus maximus (trochanteric bursa) located between the gluteus maximus and gluteus medius tendons, the subgluteus medius located deep to the insertion of the gluteus medius on the lateral facet, and the subgluteus minimus bursa deep to the insertion of the gluteus minimus on the anterior facet.

Ultrasound guidance ensures accurate needle placement into the intended bursae. In this chapter, we will present an in-plane technique, short axis to the gluteus medius tendon, which may be used to inject both the subgluteus medius and greater trochanteric bursae. We will also demonstrate out-of-plane confirmation. Safety considerations include avoiding an intratendinous injection.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 35D.1)

- Patient positioned side-lying with symptomatic side exposed.
- Patient's hips and knees can be slightly flexed for comfort.
- Interventionalist stands behind the patient (Fig. 35D.1A).
- Ultrasound image in front of the patient on the opposite side of the interventionalist and in line with the transducer (see Chapter 4).
- Begin by placing the transducer in **short axis to the femoral diaphysis,** which appears circular and rounded.
- Scan from **distal to proximal** until the greater trochanter and its anterior and lateral facets, with a characteristic triangular appearance, are visualized.
- Identify the gluteus medius and minimus tendons attaching to their respective facets; note that the greater trochanteric bursa itself is not typically visualized even with active bursitis (Fig. 35D.1B,C).
- With the transducer in axial plane, short axis to the femur, insert the needle from a **posterior to anterior direction** toward the trochanteric (subgluteus maximus) bursa.
- While visualizing the needle tip in-plane, advance until it **touches down on the lateral facet to inject the subgluteus medius bursa** (not demonstrated in this chapter). The needle is then withdrawn to a location just **superficial to the gluteus medius and deep to the gluteus maximus to inject the trochanteric bursa** (Fig. 35D.1B,C).
- If resistance is encountered while administering injectate, the needle may be embedded in the gluteus medius tendon. Slightly withdrawing or advancing the needle while injecting will produce a loss of resistance and injectate flow.

Fig. 35D.1. A, Suggested room, interventionalist, transducer, and ultrasound unit setup relative to side-lying patient.

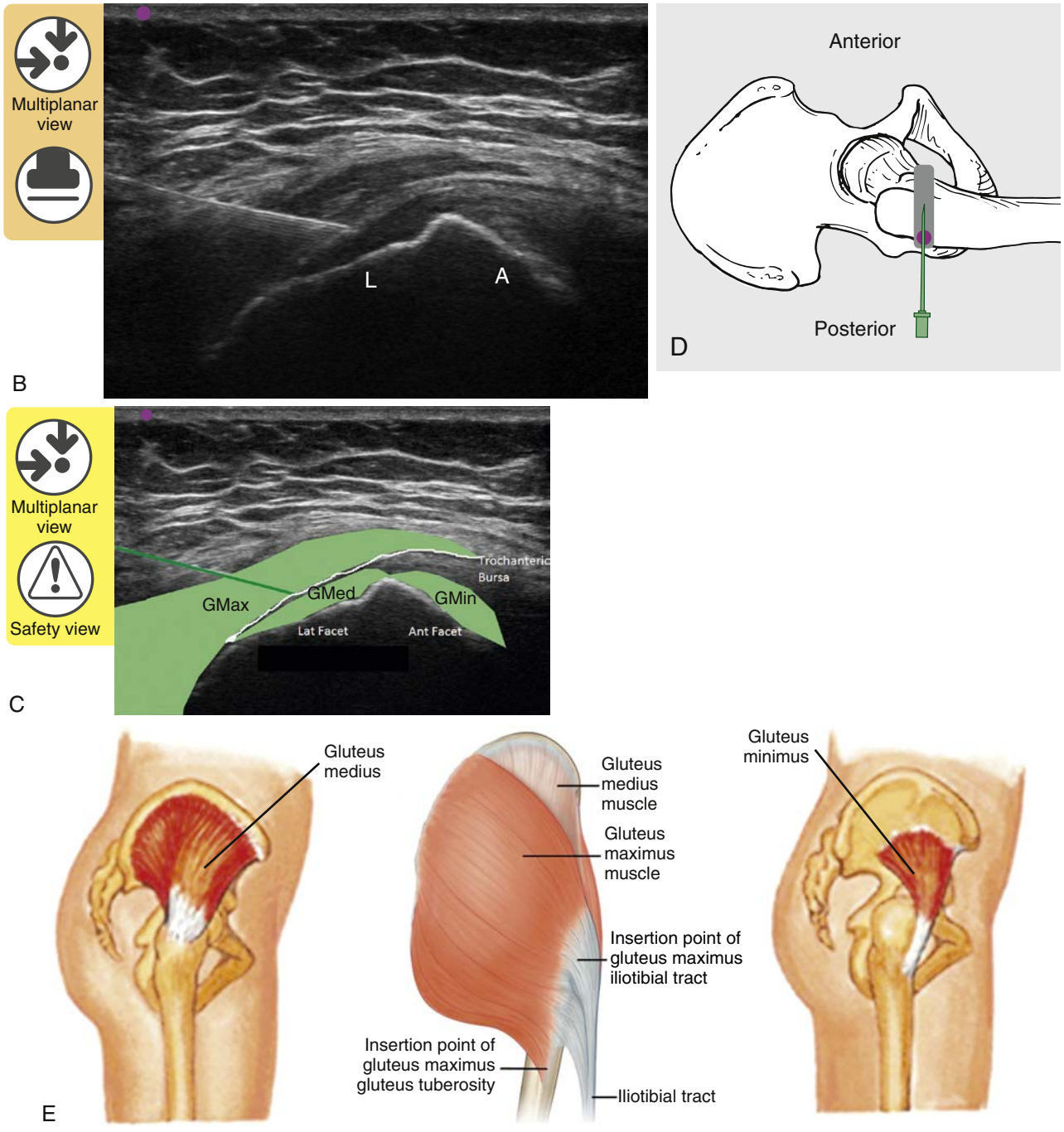

Fig. 35D.1, cont'd **B,** Ultrasound image of needle placement superficial to the gluteus medius tendon in the subgluteus maximus (trochanteric) bursa. Although a linear transducer is demonstrated, a curvilinear transducer may also be considered. L, lateral facet; A, anterior facet. **C,** Drawing of relevant structures. Needle is green. *GMed,* Gluteus medius tendon; *GMin,* gluteus minimus tendon and muscle; *GT,* greater trochanter. Trochanteric bursa in white. **D,** Skeleton showing proper placement of ultrasound transducer. Note that this is a lateral view of the pelvis and transducer is perpendicular to the axis of the femur. **1E,** Diagrammatic representation of the gluteus medius inserting posterolaterally, gluteus minumus inserting anteriorly, and gluteus maximus inserting at the gluteus tuberosity distally and continuing to form the iliotibial tract laterally.

In-Plane Technique Safety Considerations

- Avoid injecting into the gluteus medius tendon, which is immediately deep to the trochanteric bursa.
- There are no neurovascular structures that must be avoided in this approach.

Out-of-Plane Confirmation (Fig. 35D.2)

- After bursal placement with in-plane technique, rotate the transducer 90 degrees to an out-of-plane view to re-confirm bursal needle tip position.
- If the needle tip is well placed within the bursa, it should not be difficult to rotate the transducer to locate the tip as migration is unlikely.
- Needle tip should be visualized deep to the gluteus maximus and superficial to the gluteus medius.

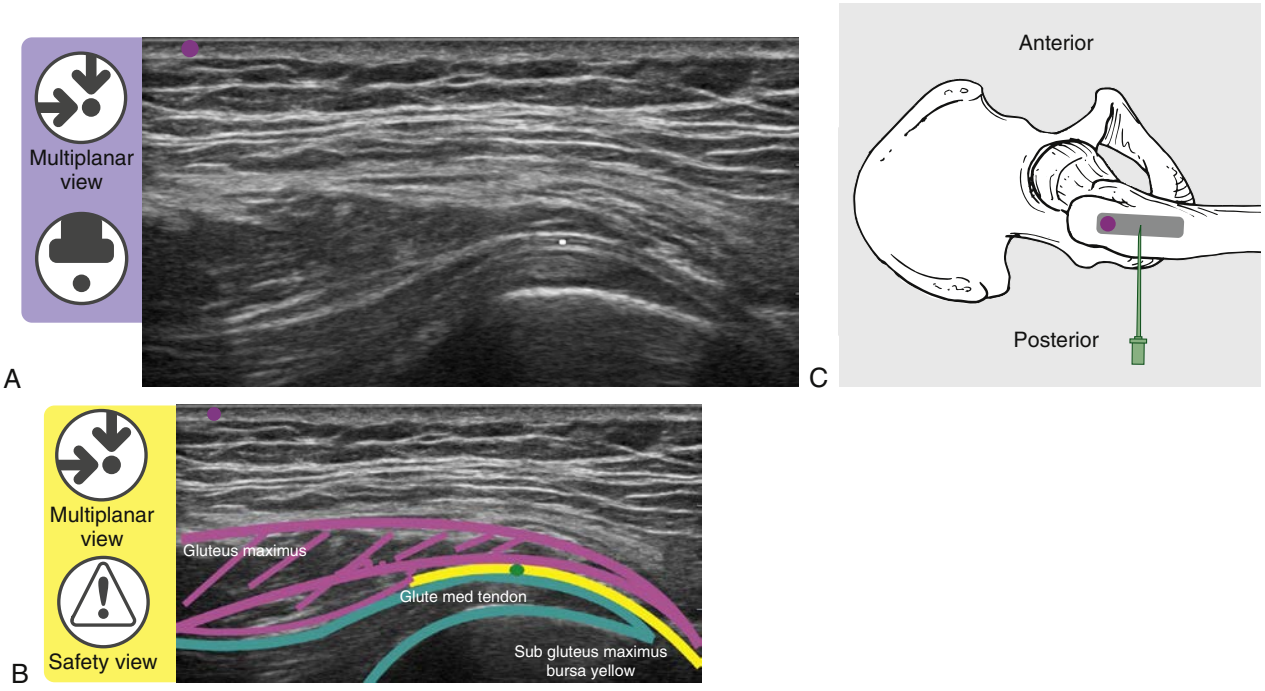

Fig. 35D.2. A, Ultrasound image of needle placement. **B,** Drawing of relevant structures. Needle is green. GMed, gluteus medius tendon; GT lat, greater trochanter, lateral facet. The sub-glueus maximus bursa is yellow. **C,** Skeleton showing proper placement of ultrasound transducer for out-of-plane confirmation. Note that this is a lateral view of the pelvis and transducer is parallel to the axis of the femur.

Out-of-Plane Technique Safety Considerations

- Avoid injecting into the gluteus medius tendon, which is immediately deep to the trochanteric bursa.
- There are no neurovascular structures that must be avoided in this approach.

Optimal Image (Fig. 35D.3)

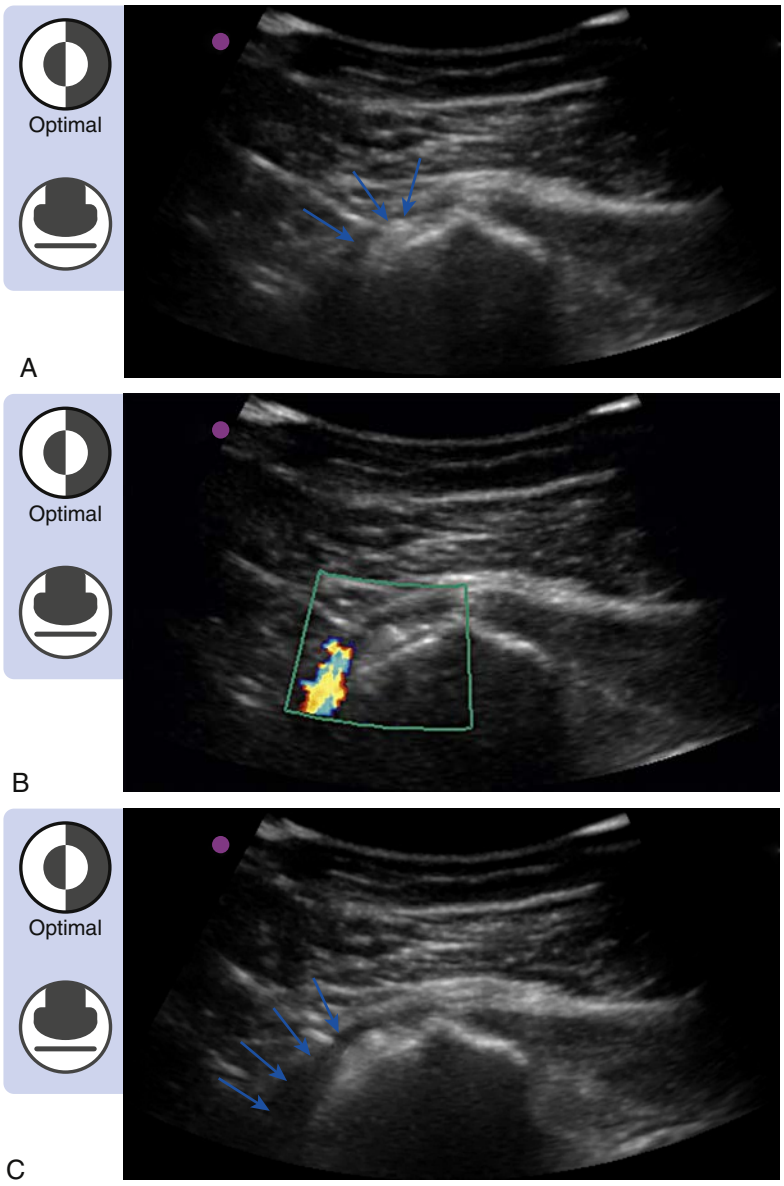

Fig. 35D.3. Optimal injection showing, **A,** focal bursal distention during initial injection (arrows); **B,** bursal flow with color Doppler; **C,** diffuse bursal distention (arrows) after administration of injectate; *GMed,* Gluteus medius tendon; *GMax,* gluteus maximus tendon.

Suggested Readings

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CHAPTER 35E

Lateral Femoral Cutaneous Nerve Injection: Ultrasound Guidance

Jackson Liu, Naimish Baxi, Jonathan S. Kirschner, and Michael B. Furman

Meralgia paresthetica (MP) is a purely sensory mononeuropathy of the lateral femoral cutaneous nerve (LFCN), which can mimic a high lumbar radiculopathy. Characterized by sensory disturbances and burning paresthesias in the anterolateral thigh, it is most commonly caused by nerve entrapment as the nerve exits the pelvis under the inguinal ligament. While 85% of patients have a favorable course, 15% may develop chronic intractable pain. The LFCN arises from the dorsal branches of the L2 and L3 spinal nerves and emerges from the lateral border of the psoas major, crossing the iliacus obliquely. It then passes under the inguinal ligament medial and inferior to the anterior superior iliac spine (ASIS). It eventually passes over the sartorius where it becomes more superficial to innervate the anterolateral cutaneous region from the thigh to the knee. The course of the nerve is known to be highly variable.

While treatment for MP is typically conservative, injections have been employed in recalcitrant cases with good success. Ultrasound guidance, especially given the variability of the nerve location, increases the accuracy of the injection. In this chapter, we will present an in-plane technique, short axis to the LFCN. We will also demonstrate out-of-plane confirmation. Safety considerations include an intraneural injection or injection of the vascular structures that travel with the nerve.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 35E.1)

- Patient positioned supine.
- Interventionalist stands to the ipsilateral side of patient (Fig. 35E.1A).
- Ultrasound image is on the opposite side of the interventionalist and in line with the transducer (see Chapter 4).
- Begin by placing the transducer **over the ASIS and parallel to the inguinal ligament**.
- Scan from **lateral to medial in a caudal direction** to locate the hyperechoic round or elliptical nerve, which is **typically visualized between the sartorius and tensor fascia latae (TFL)**.
- Because the course of the LFCN is highly variable, scanning should begin at the ASIS but may end in a more distal or medial location altogether.
- Identify the TFL and sartorius muscle; the rectus femoris tendon and muscle may be visualized more distally in the thigh (Fig. 35E.1B,C).
- Color Doppler may assist in the identification of vascular structures, which travel with the nerve.
- With the transducer in short axis to the LFCN, insert the needle from a **lateral to medial direction** toward the nerve.
- While visualizing the needle tip in-plane, advance until it **lies adjacent to the nerve between the TFL and sartorius** (Fig. 35E.1B,C).
- Injectate is then administered with resulting flow around the nerve, creating a halo effect.

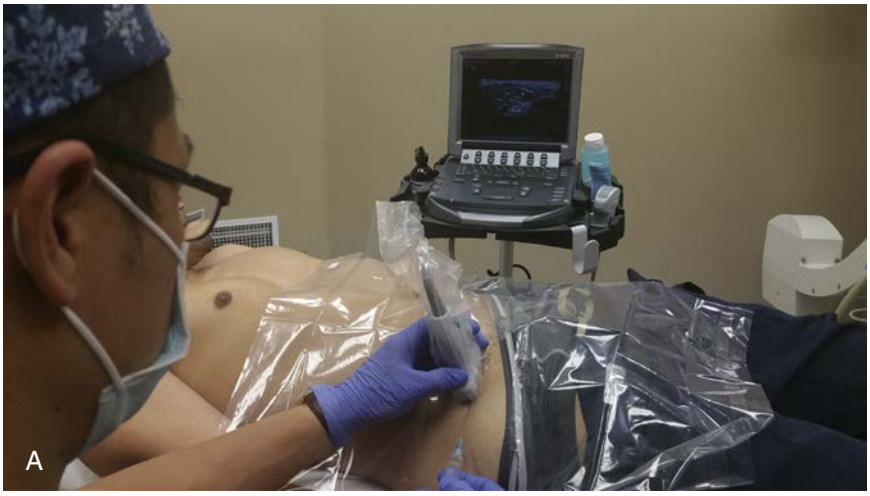

Fig. 35E.1. A, Suggested room, interventionalist, trasducer, and ultrasound unit setup relative to supine patient.

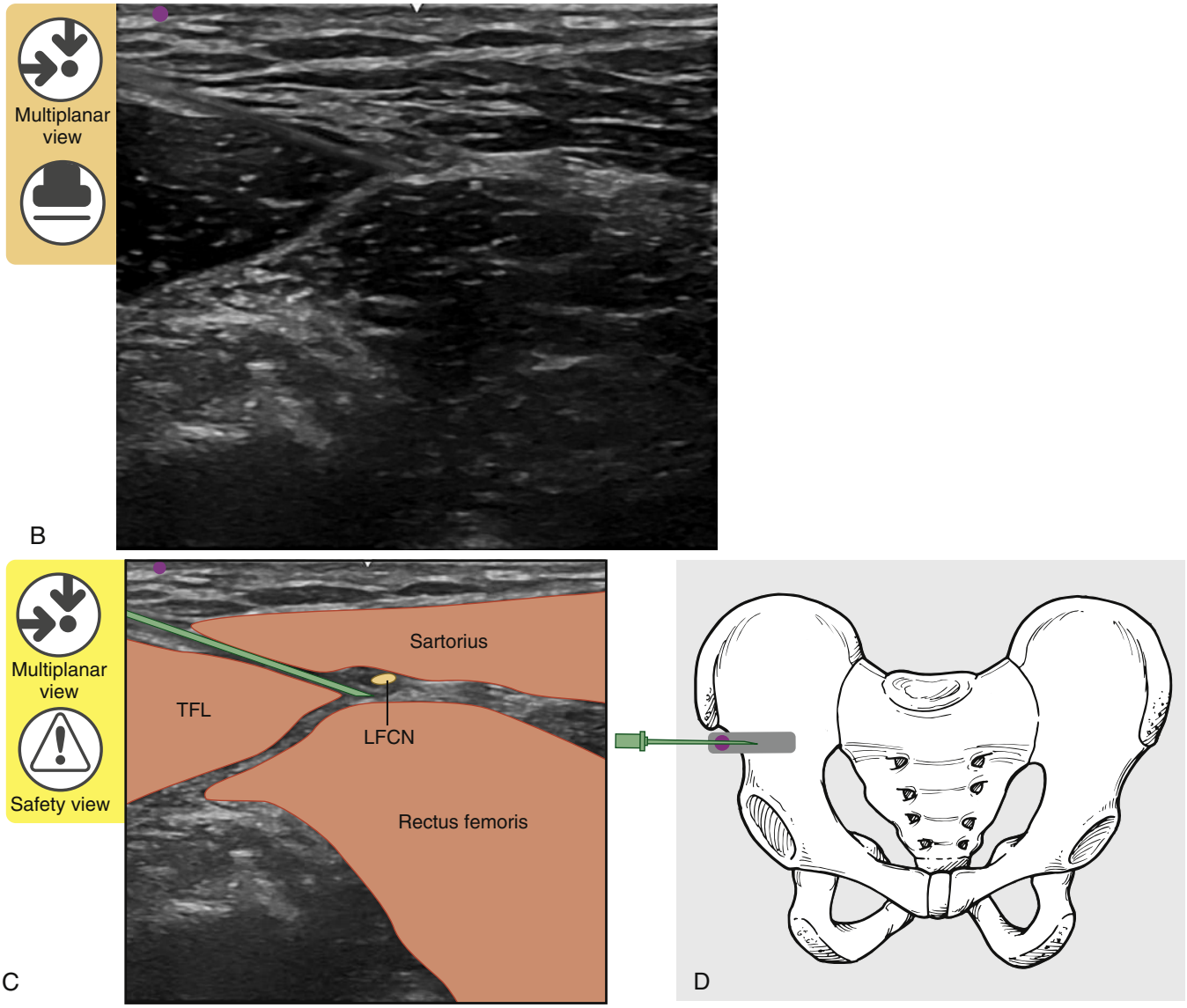

Fig. 35E.1, cont'd B, Ultrasound image of the lateral femoral cutaneous nerve needle in-plane placement in between the tensor fascia latae and the sartorius. Note that the transducer is distal to the anterior superior iliac spine in this image. **C,** Drawing of relevant structures. Needle is green. **D,** Skeleton showing the proper placement of ultrasound transducer.

In-Plane Technique Safety Considerations

- Avoid intraneural injection of the LFCN.
- Avoid injecting the artery and vein, which travel with the nerve and can sometimes be visualized with color Doppler.

Out-of-Plane Confirmation (Fig. 35E.2)

- After needle placement with in-plane technique, rotate the transducer 90 degrees to an out-of-plane view to re-confirm the needle tip position.
- If the needle tip is well placed adjacent to the nerve, it should not be difficult to rotate the transducer to locate the tip as migration is unlikely.
- Tip should be visualized adjacent to the nerve in between the TFL and sartorius.

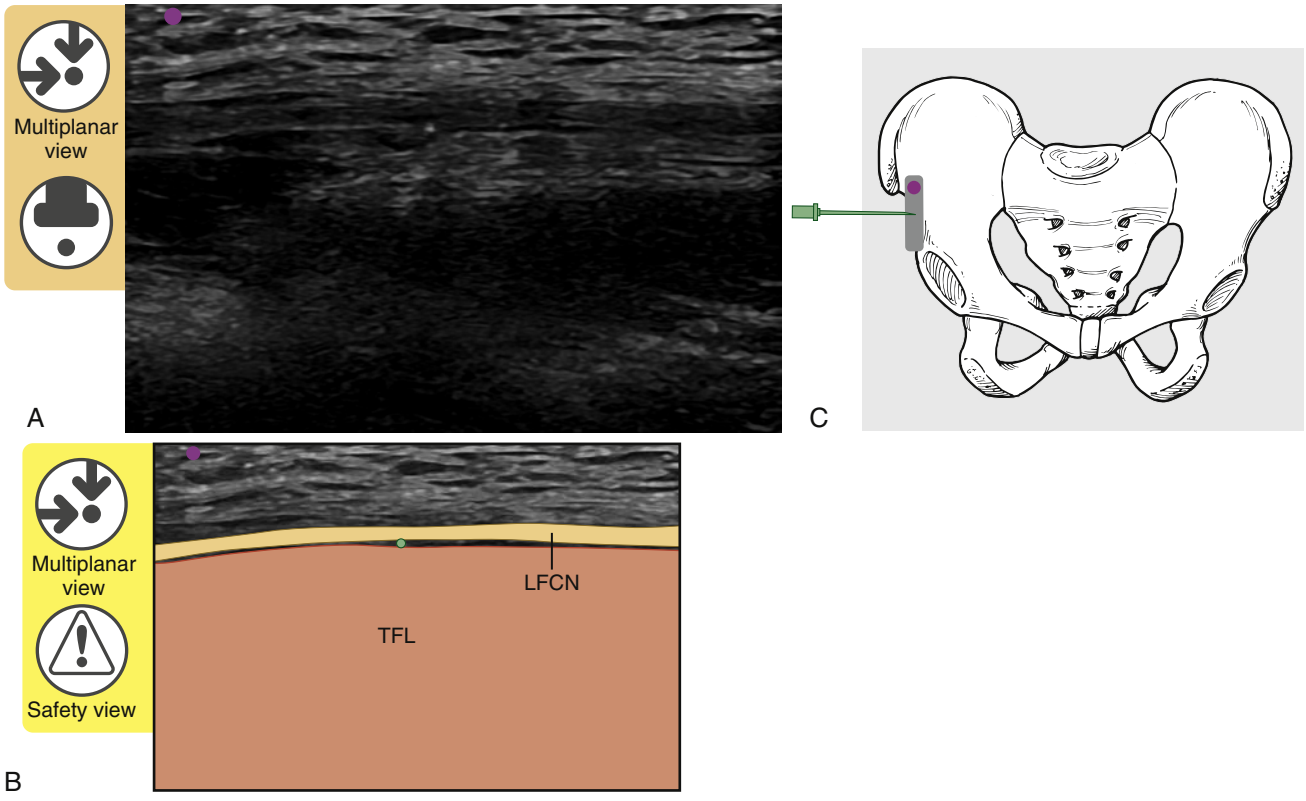

Fig. 35E.2. A, Ultrasound out-of-plane confirmation image of the lateral femoral cutaneous nerve needle placement. **B,** Drawing of relevant structures. Depending on transducer angle, either the tensor fascia lata (shown) or rectus femoris will be deep to the nerve. **C,** Skeleton showing the proper placement of ultrasound transducer for out-of-plane confirmation.

Out-of-Plane Technique Safety Considerations

- Avoid intraneural injection of the LFCN itself by visualizing the tip of needle just adjacent to the nerve.
- Alternative, more distal location for LFCN block. The nerve is found in a deeper location with this technique (Fig. 35E.3).

Alternative

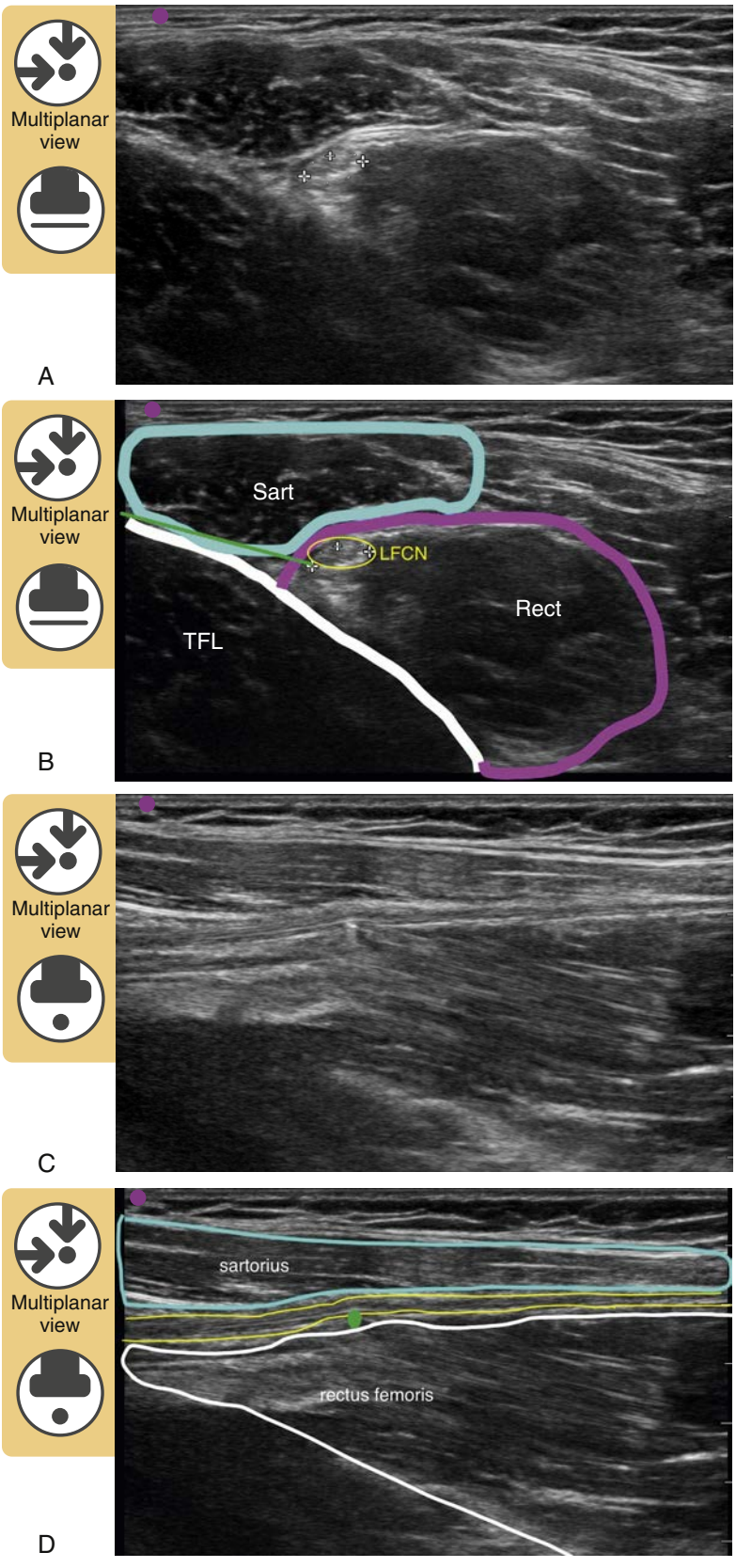

Fig. 35E.3. Alternative, more distal location for lateral femoral cutaneous nerve block. The nerve is found in a deeper location with this technique. **A,** In-plane approach. **B,** Drawing of the A in-plane approach. **C,** Out-of-plane confirmation of the same needle position. **D,** Drawing of the C out-of-plane confirmation (LFCN is yellow).

Optimal Image (Fig. 35E.4)

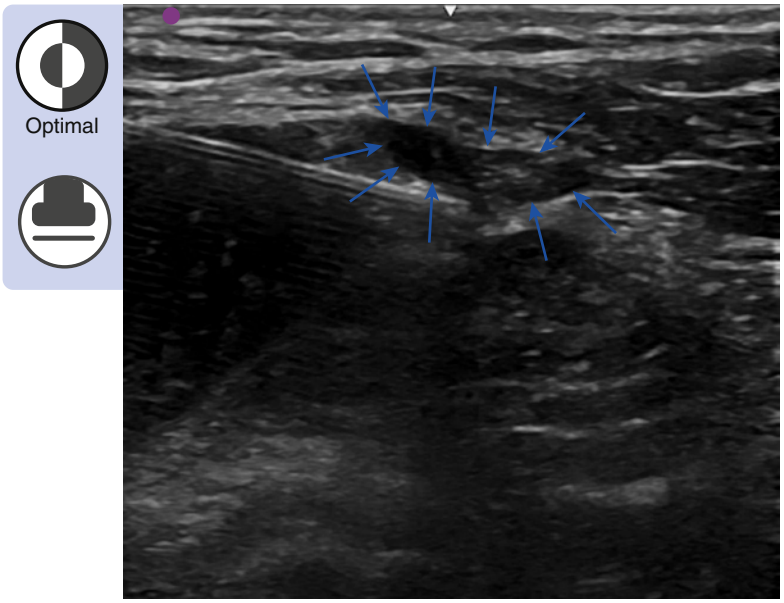

Fig. 35E.4. Optimal nerve injection showing hyperechoic injectate (arrows) surrounding the hyperechoic lateral femoral cutaneous nerve.

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CHAPTER 36

Iliac Crest Bone Marrow Biopsy/Aspiration

The use of autologous mesenchymal stem cells (MSCs) from the iliac crest bone marrow aspiration (BMA) for regenerative treatment of musculoskeletal conditions is becoming more frequently used.

Manual palpation of pelvic landmarks has been shown to have limited validity, and one study demonstrated 11.6% frequency of "dry tap" or inability to attain an aspirate. Fluoroscopy or ultrasound (US) can be utilized to aid access into the iliac crest and avoid breach of the ilium into the pelvic or abdominal cavities.

The goal of BMA is to obtain the greatest number of MSCs. MSCs have been shown to be found in high quantities in the iliac crest. These MSCs express immunomodulatory properties for therapeutic applications in regenerative medicine. Hernigou et al. described bone safety zones to maximize yield of MSCs with safe trocar placement. The preferred zone is from the posterior superior iliac spine to the portion of the ilium that is 8 to 10 cm superior. This zone avoids injury to the superior cluneal nerves.

The purpose of these chapters is to provide the fluoroscopic and US views and principles for iliac crest BMA.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

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1. Kilby J, Heneghan NR, Maybury M. Manual palpation of lumbo-pelvic landmarks: a validity study. *Man Ther*. 2012;17(3):259–262.
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CHAPTER 36A

Iliac Crest Bone Marrow Aspiration: Fluoroscopic Guidance

Bradly S. Goodman and Srinivas Mallempati

A parallel technique between the table of the ilium under fluoroscopic guidance avoids breach and allows for aspiration from multiple sites to maximize yield.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Trajectory View (Fig. 36A.1)

- The entry point for the bone marrow aspirate trocar is not more than 10 cm cephalad to the posterior superior iliac spine.
- **The image intensifier is obliqued** approximately 40 degrees contralaterally.
- **The C-arm is then tilted cranially** approximately 35 degrees.
- The ideal "setup view" delineates the medial and lateral tables of the posterior iliac crest.
- In the trajectory view, the needle should be placed parallel to the fluoroscopic beam.
- Once the trocar penetrates the cortical bone, the sharp tip of the stylet can be exchanged with a blunt tip.
- Other multiplanar imaging views should also be utilized for needle advancement.
- The needle is advanced 4 to 8 cm between the medial and lateral tables of the ilium.

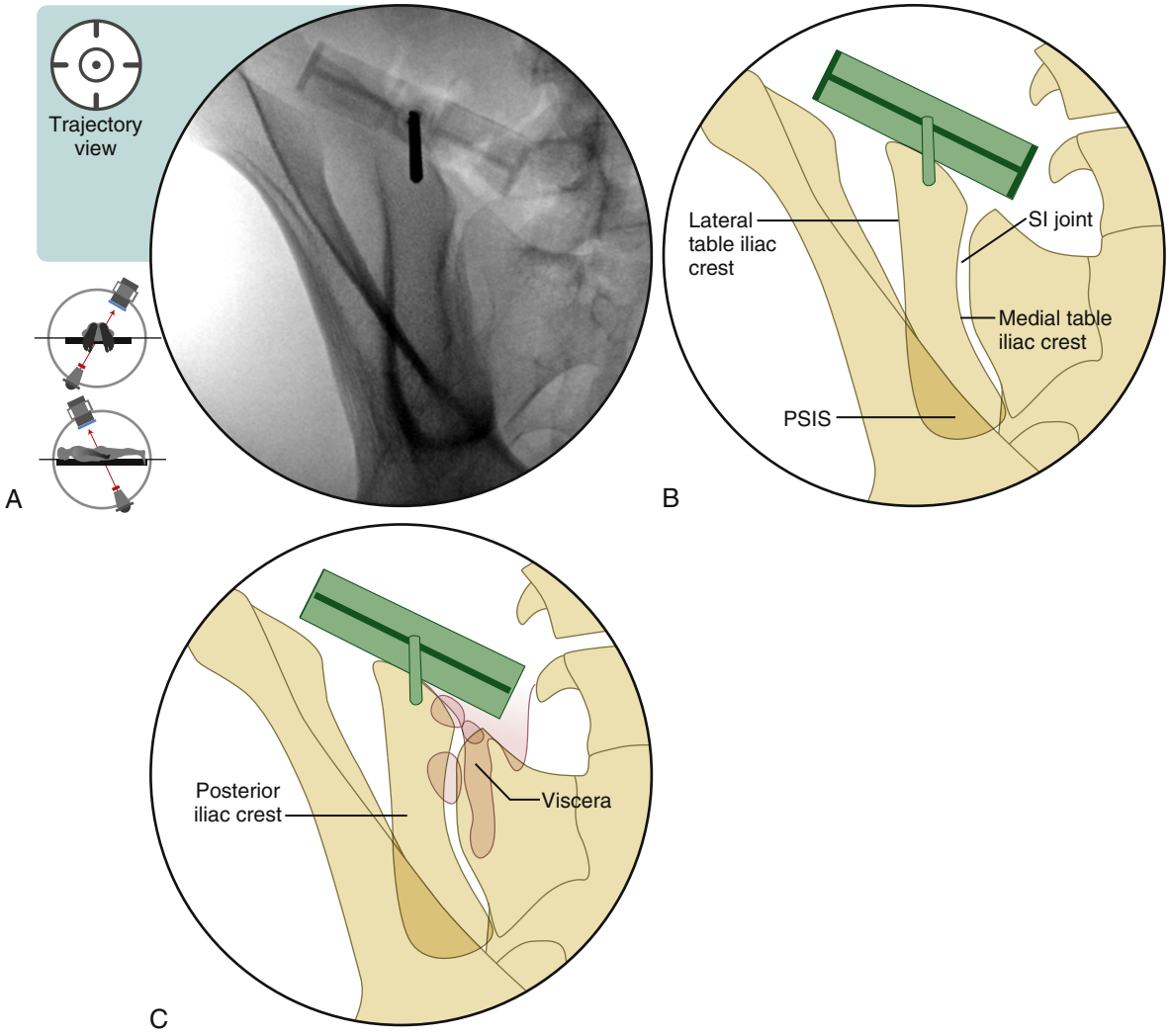

Fig. 36A.1. A, Fluoroscopic image of iliac crest biopsy, trajectory view. **B,** Radiopaque structures, trajectory view. **C,** Radiolucent structures, trajectory view.

Optimal Needle Position in Multiplanar Imaging

After the needle is placed in the trajectory view, the C-arm is tilted to an anteroposterior (AP) view (Fig. 36A.2) and the trochar tip position is confirmed with contralateral oblique (CLO) (Fig. 36A.3) and lateral (Fig. 36A.4) views.

After confirmation in multiplanar views, bone marrow is slowly aspirated in approximately 5-cc increments by rotating the needle 90 degrees and then withdrawing approximately 2 cm at a time until the desired volume is obtained.

OPTIMAL NEEDLE POSITIONING IN THE ANTEROPOSTERIOR VIEW (FIG. 36A.2)

- The AP view demonstrates the CLO and cephalocaudal path of the trocar.
- This is not the ideal view to advance the needle because the medial and lateral tables of the ilium are not delineated.
- The superior cluneal nerves are more proximal on the ilium.

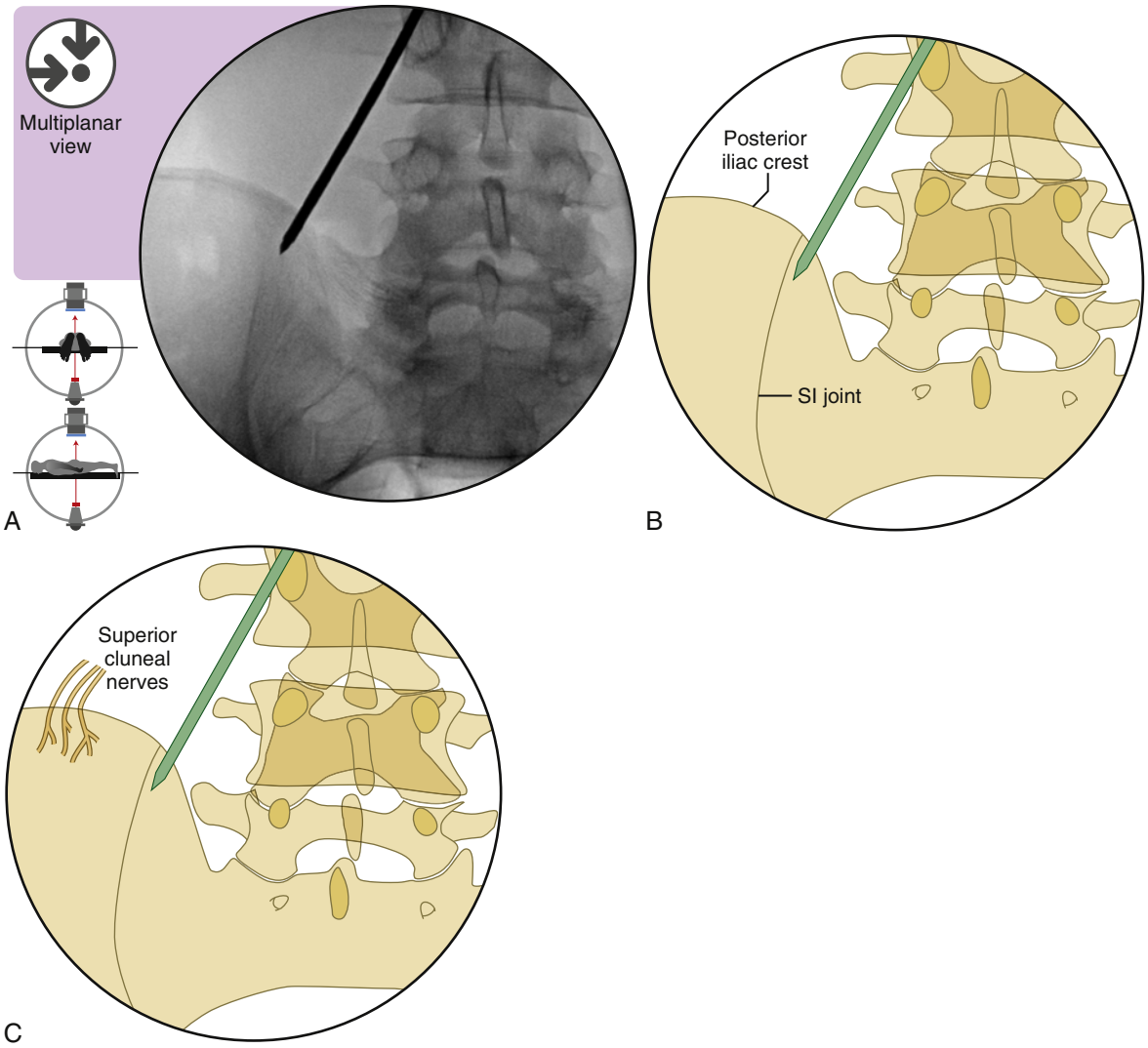

Fig. 36A.2. A, Fluoroscopic image of iliac crest biopsy, anteroposterior (AP) view. **B,** Radiopaque structures, AP view. **C,** Radiolucent structures, AP view.

OPTIMAL NEEDLE POSITIONING IN THE CONTRALATERAL OBLIQUE VIEW (FIG. 36A.3)

- The optimal CLO view is obtained when both the medial and lateral tables of the ilium are well defined as demonstrated in this image.
- The trocar can be advanced a significant distance (4–8 cm) to aspirate at different areas in the ilium.
- The trocar avoids breach of the medial and lateral tables by keeping the tip between them.
- As previously noted, once the trocar penetrates the cortical bone, the sharp tip of the stylet can be replaced with a blunt tip, further enhancing safety as far as breaching the medial or lateral table of the posterior ilium.

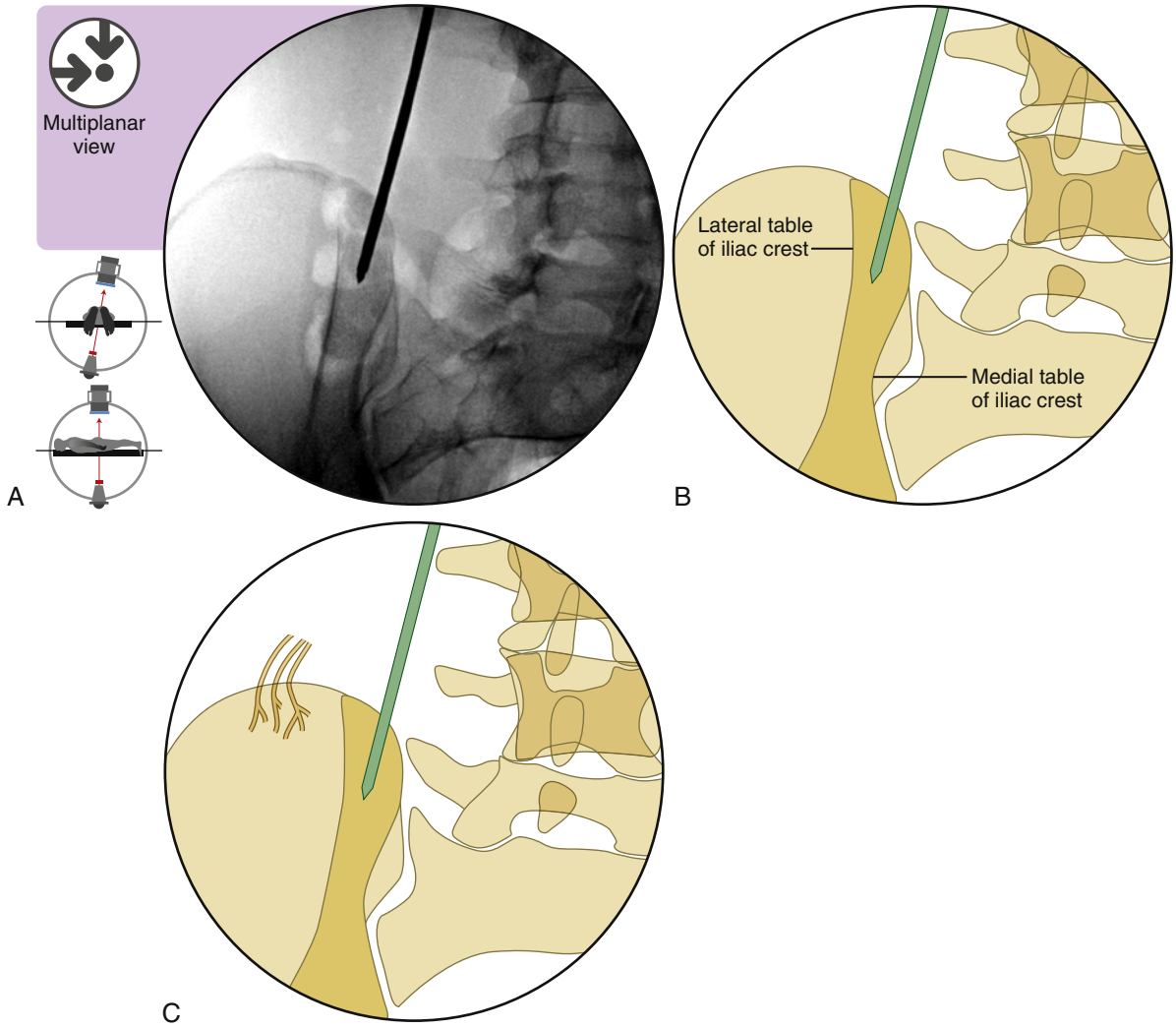

Fig. 36A.3. A, Contralateral oblique (CLO) view without cephalad tilt such that the trocar (with sharp tip in this case) can be advanced between the medial and lateral tables of the ilium. **B,** Radiopaque structures, CLO view. **C,** Radiolucent structures, CLO view.

OPTIMAL NEEDLE POSITIONING IN THE LATERAL VIEW (FIG. 46A.4)

- This view is provided to merely serve as a lateral view image reference. The needle would have to be advanced a significant length to travel too far to enter the acetabulum off the pelvis.

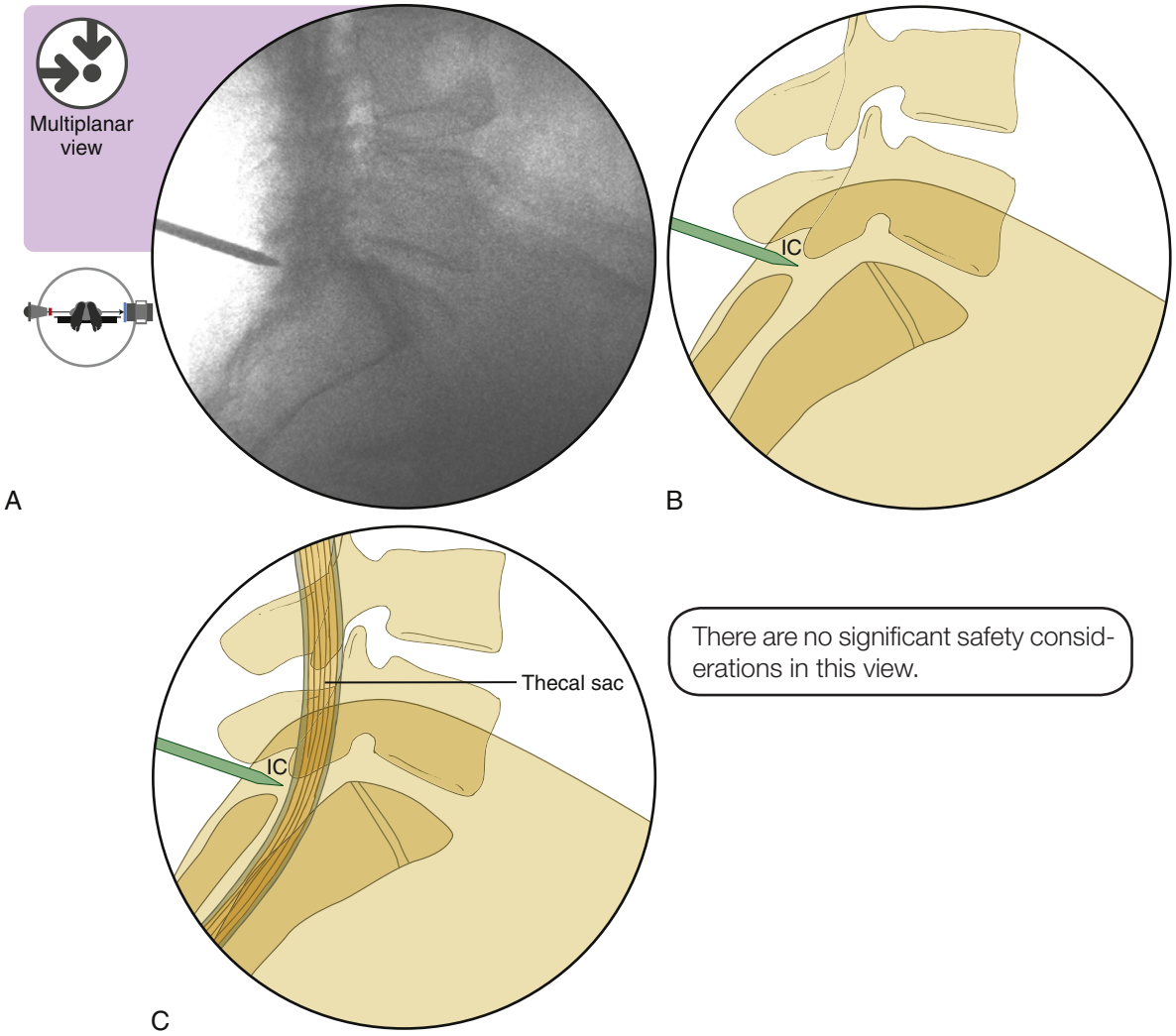

Fig. 36A.4. A, Lateral view (in a different patient from those in Figs. 36A.1 to 36A.3 above). Note that the needle trajectory is from superior to inferior. **B,** Radiopaque structures, lateral view. **C,** Radiolucent structures, lateral view.

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CHAPTER 36B

Iliac Crest Bone Marrow Aspiration: Ultrasound Guidance

Shounuck I. Patel and Vishal Thakral

Ultrasound can be used for imaging guidance to access the medullary cavity of the iliac crest while avoiding neurovascular structures and excess radiation exposure. A technique perpendicular to the tables of the ilium can be used in-plane to the ultrasound transducer. This allows for aspiration from multiple cortical sites to maximize yield of nucleated cells. An alternative technique (not described in this text) can be used that is a similar parallel approach as the described fluoroscopic technique. This alternative parallel approach would be out-of-plane to the transducer, or would use ultrasound identification of the intended target and then completion of the procedure without live guidance.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

In-Plane Technique (Fig. 36B.1)

- Patient is prone.
- Interventionalist is on the patient's ipsilateral side.
- Ultrasound image contralateral to the interventionalist and in line with transducer (Fig. 36B.1A, see Chapter 4).
- Curvilinear ultrasound transducer positioned so the palpated ipsilateral iliac crest is in the short axis.
- Scan caudad/cephalad to identify the most peaked aspect of the iliac crest. This is the cephalad aspect of the posterior superior iliac spine (PSIS).
- Mark the intended needle entry point in-plane to the transducer so that the intended needle trajectory is perpendicular to the iliac crest 1 to 2 cm below the most superficial peak (Fig. 36B.1B,C).
- Pivot from the marked entry point obliquely caudad/cephalad to identify additional intended targets on the iliac crest (Fig. 36B.1D). When pivoting caudad, the peak of the iliac crest will start to flatten at the level of the PSIS (see Fig. 36B.3A). When pivoting cephalad, the peak of the iliac crest will start to thin at the superior aspect (see Fig. 36.3C).
- Identify any neurovascular structures lateral to the iliac crest in the needle guidance track.
- Insert needle/trocar and advance in-plane to the transducer from lateral to medial.
- Advance trocar into subcortical medullary cavity.
- Once the trocar is advanced into the medullary cavity, it cannot be visualized with ultrasound.
- After advancing the trocar into the medullary cavity, fluoroscopic image may be taken with the C-arm in an identical setup as the above described contralateral oblique trajectory view (Fig. 36B.2).
- Bone marrow is slowly aspirated in approximately 5-cc increments up to 10 to 15 cc from any one given site.
- The trocar can then be gently removed from the cortex and repositioned using the same skin entry point to additional intended targets with different trajectories on the iliac crest as shown (Fig. 36B.1D).

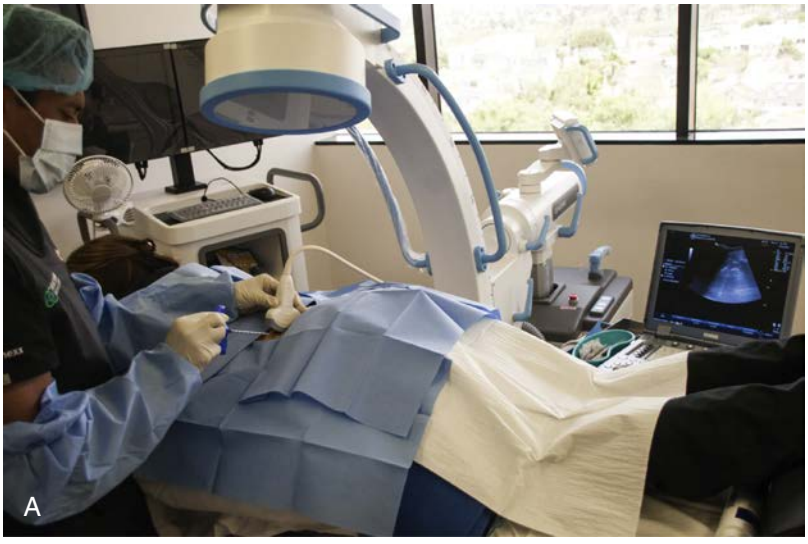

Fig. 36B.1. A, Typical room, interventionalist, US transducer, and US unit setup for hybrid procedure with with fluoroscopic and ultrasound guidance.

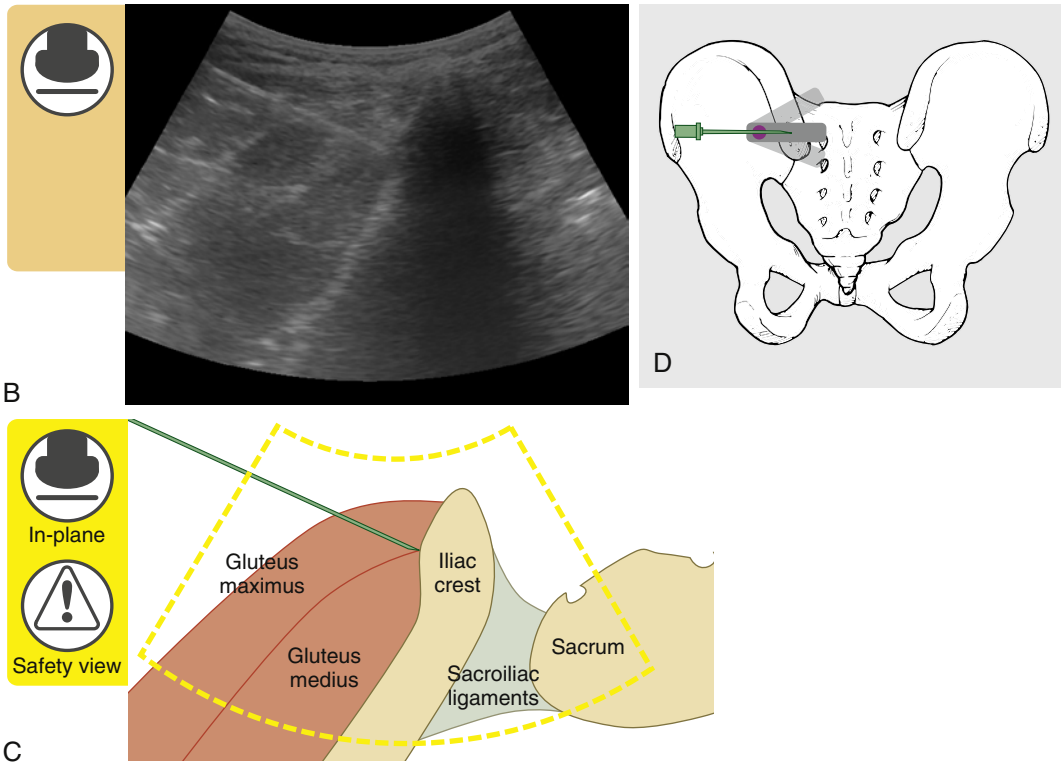

Fig. 36B.1. cont'd B, Ultrasound image of trocar placement within the iliac crest in short axis. **C,** The relevant radiolucent structures. Yellow dashed line represents borders of the image seen on ultrasound in **B. D,** Skeleton with transducer placement. Opaque transducer represents the starting point at the superior aspect of the posterior superior iliac spine. Semi-opaque probes represent additional trocar trajectories into the iliac crest.

In-Plane Technique Safety Considerations

- A "loss of resistance" is appreciated when penetrating the lateral table into the subcortical medullary cavity.
- Fluoroscopy in contralateral oblique view (Fig. 36B.3) may also be performed until the end-feel of entering the medullary cavity is mastered.
- If too medial, the trocar can penetrate the crest into the underlying sacroiliac joint/ligaments.
- Consider changing from a sharp introducer trocar to a blunt one once the lateral table of the cortex is penetrated to avoid medial table penetration.
- If penetrating the medial table is suspected, injection of saline with Doppler ultrasound can visualize extravasation.
- Further safety can be achieved by changing from a sharp introducer trocar to a blunt one once the lateral table of the cortex is penetrated.

Optimal Images (Figs. 36B.2 and 36B.3)

- At the level of the PSIS, the cortex is flatter than the most peaked point (Fig. 36B.3C).
- The iliac crest is peaked at the cephalad aspect of the PSIS (Fig. 36B.3C).
- The iliac crest is thinner superior to the PSIS (Fig. 36B.3C).
- Optimal trocar placement under fluoroscopy in between the tables of the iliac crest at the level of the PSIS (Fig. 36B.4A), cephalad to the PSIS (Fig. 36B.4B), and at the superior aspect of the iliac crest (Fig. 36B.4C).

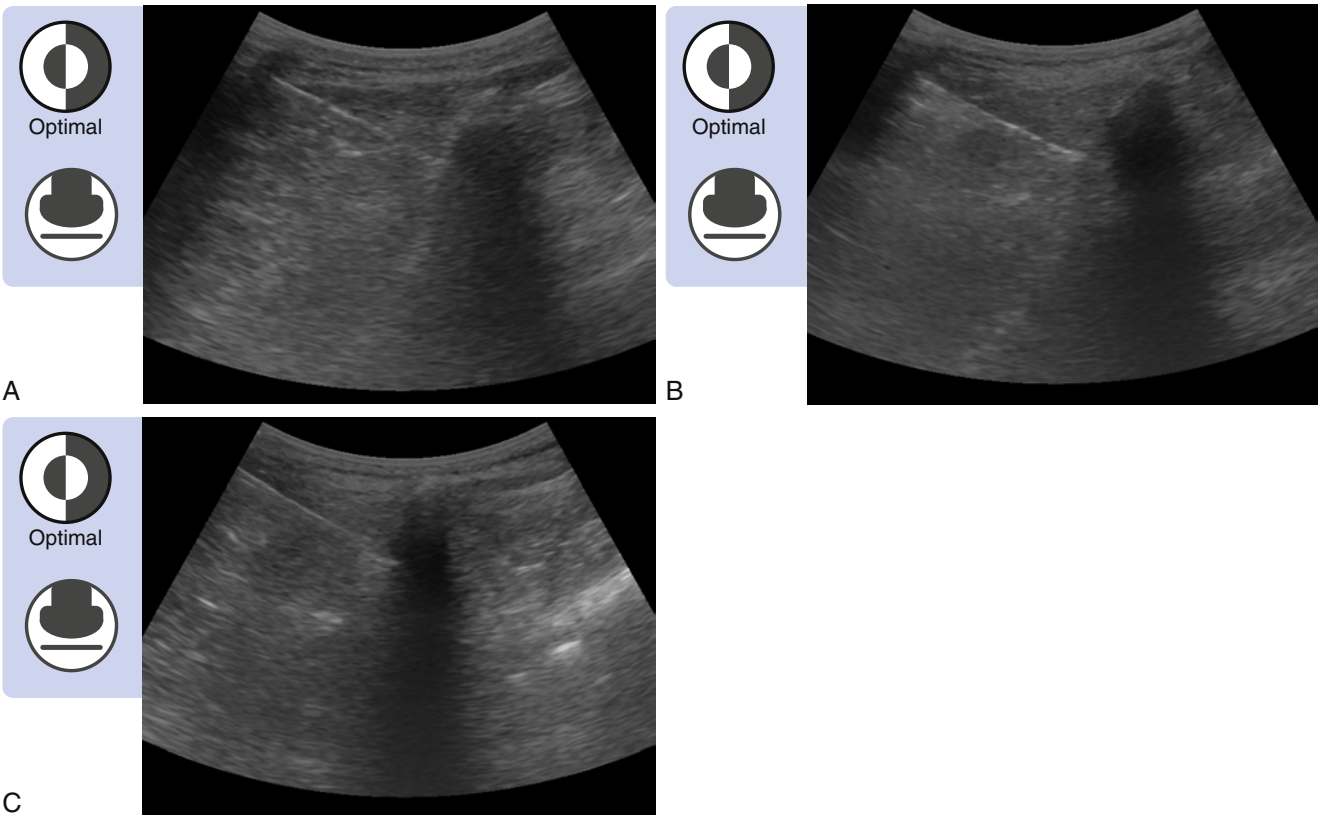

Fig. 36B.2. Three different ultrasound trajectories to correspond to trajectories shown in Fig. 36B.1C. **A,** Trocar at the level of the posterior superior iliac spine (PSIS). **B,** Trocar just cephalad to the PSIS. **C,** Trocar at the superior aspect of the iliac crest.

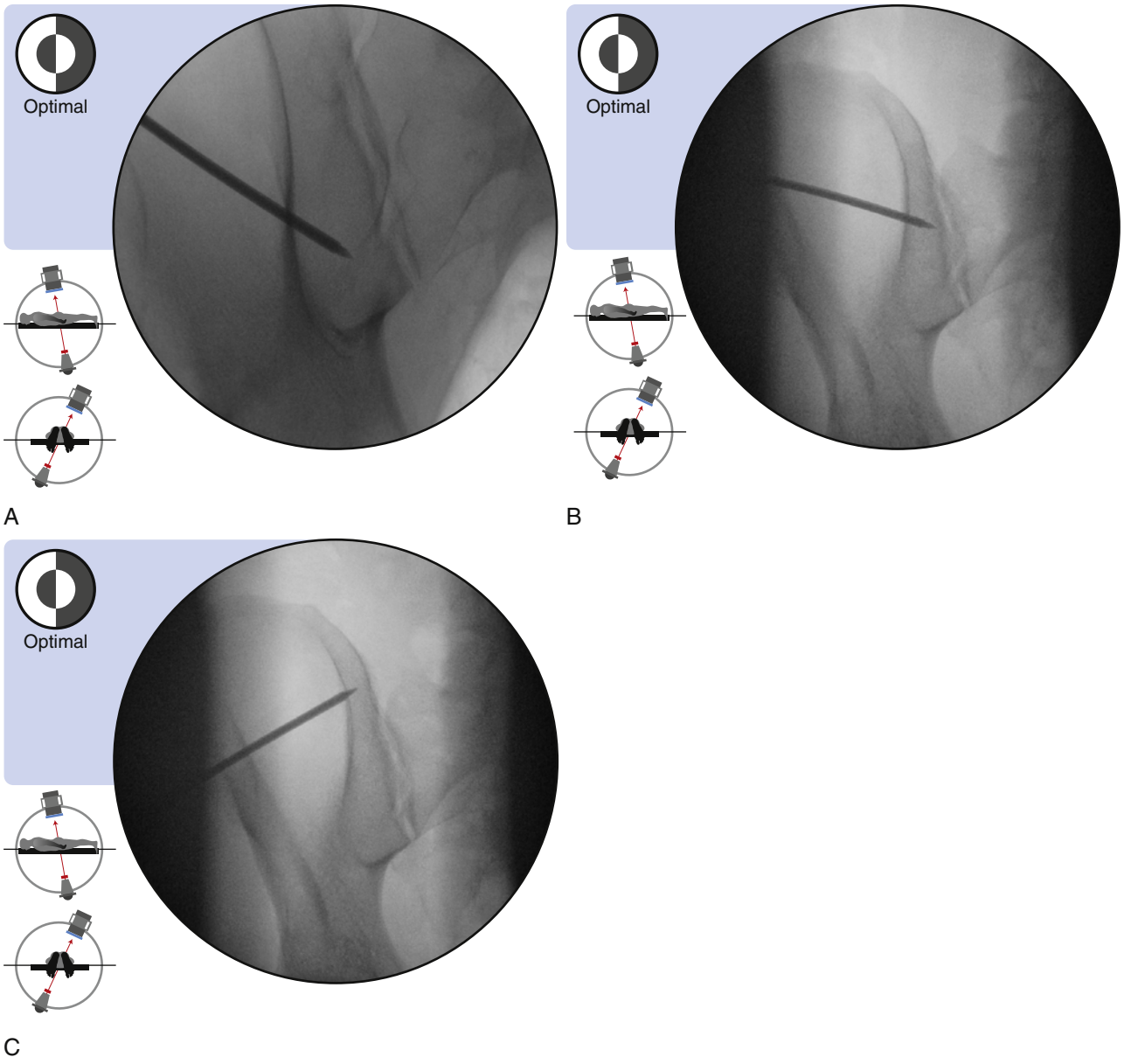

Fig. 36B.3. Fluoroscopic images to correspond to the Fig. 36B.2 ultrasound trajectories depicting the trocar tip between the medial and lateral tables in the iliac crest without penetration of the medial table. **A,** Trocar at the level of the posterior superior iliac spine (PSIS). **B,** Trocar just cephalad to the PSIS. **C,** Trocar at the superior aspect of the iliac crest.

Suboptimal Needle Placement and Images (Fig. 36B.4)

- Trocar trajectory that is too steep risks penetrating the thinner iliac table into the underlying abdominal/pelvic cavity (Fig. 36B.4A).
- Trajectory that is too shallow risks entering and exiting the cortex without entering the medullary cavity (Fig. 36B.4B).
- If too medial, the trocar can penetrate the crest into the underlying sacroiliac joint/ligaments (Fig. 36B.4C).

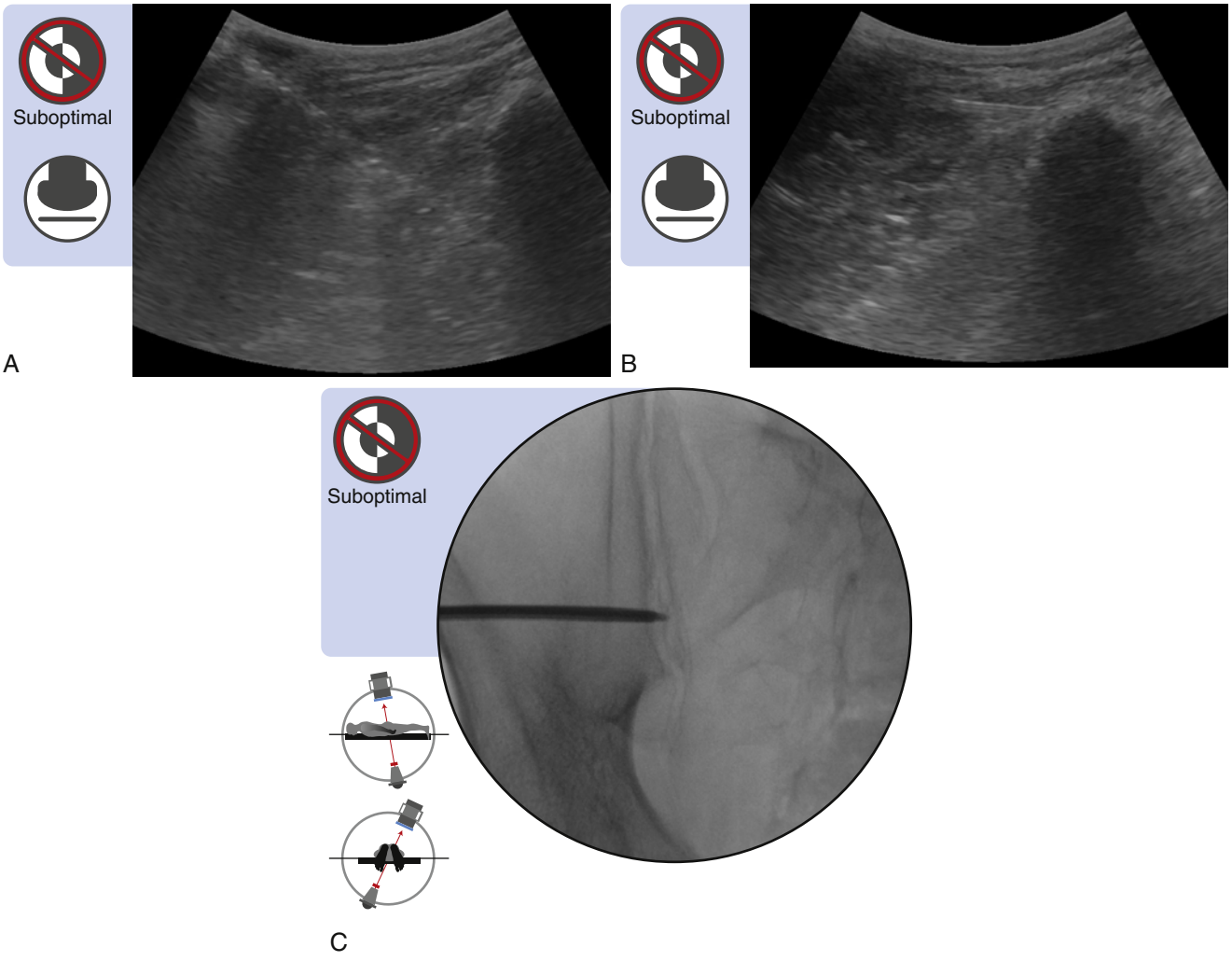

Fig. 36B.4. A, Trocar trajectory too steep under ultrasound guidance. **B,** Trocar trajectory too shallow under ultrasound guidance. **C,** Trocar too deep in fluoroscopic confirmation.

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Spinal Intervention Reference Tables and Guidelines

Gene Tekmyster, Sridhar Vallabhaneni, Bradly S. Goodman, and Michael Furman

INTRODUCTION

These appendices are a reference for the spinal interventionalist. They include the following:

- An antiplatelet/anticoagulant discussion/reference
- A steroid equivalency table
- A local anesthetic dose reference guide
- A medication regimen for patients with a history of a prior reaction to radiocontrast media
- An intrathecal contrast and dose reference

For topical and antiseptic skin treatment agents, please see Chapter 5. Table 5.1 lists the most commonly used skin preparation/sterilization agents.

Note: Please see pages ii and iii for a list of anatomic terms/abbreviations used throughout this book.

Appendix A1
Anticoagulation and Antiplatelets

When considering a patient for interventional spine procedures, we cannot simply ask "How long do I hold each medication preprocedure?" Considering the potential risks associated with cessation of these medications, instead, we suggest **a logical and more comprehensive approach based on each patient's unique medical and procedural situation.**

In the clinical setting of general musculoskeletal and spine medicine, it is always important to approach this scenario with a logical approach. For each patient, we suggest addressing it within the context of asking ourselves these questions:

1. **Why is the patient receiving the anticoagulant (AC)/antiplatelet (AP) medication?**
2. **What is the risk of stopping it?**
3. **Is the procedure truly warranted, or can it be changed to a less risky intervention?**
4. **What is the risk of performing the chosen procedure without holding the medication?**

For each patient and procedure, a risk/benefit analysis should be performed. We need to compare the risk of holding the AC/AP medication to that of performing the procedure while the patient is on the AC/AP medication. In regards to the first two questions posed above, **risk of thrombosis and medical complications is much higher due to cessation of AC/AP medication**, with some studies reporting as high as a 5- to 10-fold increase in mortality. **Cessation of AC/AP medication can potentially lead to a life-threatening event such as myocardial infarction. The risk of adverse events can be as much as 2- to 3-fold higher for stroke and 5- to 6-fold higher for other major vascular events within the first 30 days of cessation**. There also is evidence that **platelet inhibition can begin to reverse in as little as 3 to 5 days**, thereby further increasing the risk for thrombosis in the short term. Certain recent studies have shown that medical **morbidity is a significant and quantifiable risk when discontinuing AC/AP** medication with minimal, if any, complications due to continuation of the said medication. In particular, the authors found no complications with continuing AC/AP medications when performing spine interventions. In contrast, of the patients who discontinued the recommended therapy, nine suffered significant morbidity, including two deaths, five strokes, one pulmonary embolism, and one myocardial infarction, all occurring within 2 to 5 days of AC/AP therapy cessation.

Therefore, we must address the need for a planned intervention. We recommend that procedural indications be judiciously considered and confirmed in all patients. However, we should be especially cautious for those patients who are on AC/AP medications. In particular, the decision to discontinue dual-AP medications, i.e., P2Y12 inhibitor (clopidogrel [Plavix]) and aspirin, must be weighed against the potential risk of cessation. Currently, there is considerable debate regarding the duration that dual-AP therapy (DAPT) should be continued after percutaneous cardiac intervention with drug-eluting stents (DES) or bare-metal stents. For DES, it is commonly accepted that the risk of stent restenosis is much higher in the first year after stent placement (prior to the occurrence of epithelialization over the stent); therefore, DAPT cannot be discontinued during that period without significant risk of stent thrombosis. As data from new studies regarding the ideal duration of treatment with DAPT is being generated, there is conflicting information. The increased risk of bleeding on DAPT treatment is balanced against the reduction in late stent thrombosis with major cardiac event. In patients for whom the risk/benefit ratio favors prolonged therapy, the optimal duration of therapy remains unknown. For high-risk spinal interventional procedures, which require full platelet function to reduce the likelihood of a bleeding event, the above historical information is helpful to guide a conversation regarding risk versus benefit, and arrive at the informed decision required to determine whether DAPT treatment should be discontinued or whether to change the proposed procedure.

The biggest concern for performing spinal interventions on a patient who was anticoagulated is the potential for bleeding, subsequent epidural hematoma, and associated devastating neurologic sequelae. Although bleeding can occur with many procedures, interlaminar (IL) procedures are most concerning for this potential adverse outcome. However, there is no definitive research that demonstrates an increased risk of epidural hematomas during IL epidural steroid injections. Recent articles have shown that the relative bleeding risk is higher in the AC/AP population; however, this risk is not statistically significant. Literature also reveals that the risk of bleeding from epidural injections is estimated at 1:18,000 to 1:150,000, even in patients who are fully anticoagulated. Particularly in patients receiving aspirin and heparin, the rate of epidural hematoma has been estimated to be at most 1/8500. Some studies, however, include catheter removal for epidural anesthesia and do not distinguish between catheter removal and single injection using a smaller-gauge needle.

Guidelines and protocols regarding the perioperative recommendations and risks of continuing AC/AP medications have been largely reflective of anesthesia-based literature, which many times includes epidural catheter preoperative anesthesia procedures. Even with strict adherence to guidelines there have been reported cases of epidural hematoma. **For cases where it**

has been determined and decided that the AC/AP medication can be safely discontinued prior to an intervention, we have composed a table reflecting the most common medications and their associated properties with consideration of the second edition of the Spine Intervention Society (SIS) Guidelines. Our goal in establishing these specific recommendations is to establish guidelines that are specific to each patient and individual procedure.

We have presented the information in two ways (see Box A1.1, below). Because each clinical scenario differs from patient to patient, the risk stratification table (Table A1.1A) and medication table (Table A1.1B) will help clinicians in clinical reasoning of the patient on AC/AP therapy.

Tables A1.1A and A1.1B are for interventional practitioners who work with patients with a known reason for AC/AP medication and matched clinical scenarios, where the interventional practitioner is **comfortable with the risk stratification grid in Table A1.1A.**

Table A1.2 is for interventional practitioners who deferr decisions regarding medication to the AC/AP prescriber, with most common AC/AP medications listed.

Tables A1.1B and A1.2 contain a list of the most common medications with suggested hold/continue recommendations, which were derived from the interpretation of available data presented in the second edition of the SIS Guidelines and the 2015 ASRA recommendations.

Box A1.1 How to Use the Anticoagulation/Antiplatelet (AC/AP) Tables

Option for practitioner:	Use table:
• Patient with known reason for AC/AP medication; interventional practitioner comfortable with risk stratification grid in Table A1.1A	• Tables A1.1A and A1.1B
• Practitioner more comfortable deferring decisions regarding hold/continue to AC/AP prescriber	• Table A1.2

Table A1.1A Stratification of Risk

	Low Risk	High Risk		
Low Risk of Holding Medication ↓ **High Risk of Holding Medication**		C, T, L, MBB L disc stimulation SI joint injection Transforaminal (L1-L5) Z-joint injection (post approach)	AO/AA joint injection Caudal ESI C, T disc stimulation C, T, S1 transforaminal ganglion impar block IL lumbar ESI Lumbar sympathetic block Kyphoplasty/ vertebroplasty Myelogram/intrathecal medication trial RFA Stellate ganglion block	Cervical/thoracic IL-ESI Intrathecal or epidural catheter Spinal cord stimulation
	ASA 81 mg, secondary prevention			
	Afib: CHADS2 score <2			
	Afib: CHADS2 score ≥2			
	History of MI			
	Recent stent (<6 months)			
	Recent stent (3-12 months)			
	Mechanical valve			
	Recent PE/DVT			

For yellow area, see Table A1.1B as described below.

If stopping or holding AC/AP medication is in consideration, discussion with the prescribing physician is recommended, as per the second edition of SIS Guidelines. In addition, if the decision to hold is made please refer to Table A1.1B for optimal timeline for holding the medication, based on 2015 ASRA guidelines.

Color key:

Green: Continue AC/AP medication.

- However, be sure to review the potential bleeding risks with the patient.
- If the decision to continue warfarin has been made, we also recommend to check INR preprocedure:
  - If INR >3.5, postpone the procedure until INR is at acceptable level
  - INR should be at the lowest possible therapeutic level in the recommended range (e.g., if range is 2-3, aim for 2)

Yellow: Consider one of the following due to bleeding risk:

- Postpone procedure if there is an end date for medication (e.g., clopidogrel for recent stent or warfarin for recent PE/DVT)
- Change the proposed intervention to one with a lower procedural/bleeding risk
- Hold medication as per Table A1.1B after reviewing with the prescribing physician

When suggesting cessation of medication (yellow), coordinate and confirm with the prescribing physician (as per the 2nd edition of SIS Guidelines). Also, review risks of stopping the procedure with the patient (moderate procedural risk for bleeding and complications). For those patients who fall into this category it is important to note:

- Why is the patient receiving the AC/AP medication?
- What is the risk of stopping it?
- Is the procedure truly warranted, or can it be changed to a less risky intervention?
- What is the risk of performing the chosen procedure without holding the medication?

Red: Consider one of the following due to significant bleeding risk:

- Postpone procedure if there is an end date for medication (e.g.,clopidogrel for recent stent or warfarin for recent PE/DVT)
- Change the proposed intervention to one of less procedural/bleeding risk
- Cancel the procedure

Table A1.1B Most Commonly Used Medications in Clinical Practice, Their Mechanisms of Action, Clinical Indications, and Hold Times

Medications	Hold Time	Mechanism of Action and Clinical Indication
ASA	Hold 6 days	MOA: ASA blocks COX, preventing production of thromboxane A2, which decreases platelet aggregation Typical USE: Prophylaxis and Tx for MI & CVA
NSAIDs	Hold 1-4 days*	MOA: NSAIDs block COX, preventing production of thromboxane A2, which decreases platelet aggregation Typical USE: Inflammation & pain management
Coumadin/Jantoven (warfarin)	Hold 4-5 days, INR <1.4 on day of procedure (If continuing procedure, INR should be at lower of therapeutic range)	MOA: Inhibits Vitamin K dependent clotting factors II, VII, IX, X Typical USE: Prophylaxis and Tx for DVT/PE, atrial fibrillation, cardiac valve replacement
Plavix (clopidogrel)	Hold for 7 days as per SIS Guidelines 2nd Ed. (change from 10 days)	MOA: Inhibition of ADP induced platelet aggregation Typical USE: Prophylaxis of cerebrovascular thromboembolic events
Aggrenox (ASA/diprydamole)	Hold 7 days as per PASSOR guidelines 2008 (change from 10 days)	MOA: Additive antiplatelet effects of dipyridamole and aspirin Typical USE: Stroke 2nd prevention
Ticlid (ticlopidine)	Hold for 14 days	MOA: Inhibition of ADP-induced platelet aggregation Typical USE: Prophylaxis of cerebrovascular thromboembolic events
Persantine (dipyramidole)	Hold for 7 days	MOA: Inhibits the uptake of adenosine into platelets, endothelial cells, and erythrocytes Typical USE: Postoperative prophylaxis of cardiac valve replacement
Effient (prasugrel)	Hold 7 days	MOA: Irreversible antagonist of the platelet ADP P2Y(12) receptor Typical USE: Acute coronary syndrome in patients undergoing PCI
ReoPro (abciximab)	Hold 48 hours	MOA: Platelet GP IIb/IIIa inhibitors Typical USE: Acute coronary syndrome
Lovenox (enoxaparin)	Hold LMWH 12-24 hrs as per SIS Guidelines 2nd edition	MOA: Binds to antithrombin, inhibiting factor Xa Typical USE: DVT/PE Prophylaxis & Tx, myocardial Infarction bridge therapy w/warfarin
Heparin Sodium (heparin)	Unfractionated Heparin (does not need to be held if under 5000 U BID as per SIS Guidelines 2nd Ed.)	MOA: Binds to antithrombin, inhibiting factor Xa Typical USE: DVT/PE prophylaxis & Tx
Arixtra (fondaparinux)	Hold 48 hours	MOA: DVT/PE Prophylaxis & Tx Typical USE: Irreversibly inhibits Xa
Pradaxa (dabigatran)	Hold for 7 days	MOA: Reversibly inhibits both free and clot bound thrombin Typical USE: Nonvalvular atrial fibrillation
Xarelto (rivaroxaban)	Hold 3 days*	MOA: Reversibly inhibits activated factor Xa Typical USE: DVT/PE prophylaxis & Tx
Trental (pentoxifylline)	Hold 2 days	MOA: Unclear, improves erythrocyte flexibility improving peripheral blood flow Typical USE: Intermittent claudication
Eliquis (apixaban)	Hold 3 days	MOA: Factor Xa (FXa) inhibition Typical USE: DVT/PE prophylaxis cerebrovascular thromboembolic prophylaxis for atrial fibrillation

See accompanying yellow section in Table A1.1A.
This table lists the pharmacokinetics and timeframe for holding the AC/AP medication, if necessary. Decision making should involve a thorough discussion of the risks and benefits with the patient and prescribing physician. The information presented here is based on our data and our interpretation of the 2nd edition of the SIS Guidelines and 2015 ASRA guidelines.

Table A1.2 Alternative Approach (NOT associated with Tables A1.1A and A1.1B)

Medications	Low Risk	Spine Procedure →	High Risk
	C, T, L, MBB L Disc Stimulation SI Joint Inj Transforaminal (L1-L5) Z-Joint injection (post approach)	AO/AA Joint Inj Caudal ESI C, T Disc Stimulation C, T, S1 Transforaminal Ganglion Impar Block IL Lumbar ESI Lumbar Sympathetic Block Kyphoplasty/Vertebroplasty Myelogram/Intrathecal medication Trial RFA Stellate Ganglion Block	Cervical/Thoracic IL-ESI Intrathecal or Epidural Catheter Spinal Cord Stimulation
ASA	Continue	Continue	
NSAIDs	Continue	Continue	
Coumadin (warfarin)	Continue (Check Pre-op INR)	Hold 4-5 days, INR <1.4 on day of procedure	
Plavix (clopidogrel)	Continue	Hold for 7 days as per SIS Guidelines 2nd Ed. (change from 10 days)	
Aggrenox (ASA/diprydamole)	Continue	Hold 7 days as per PASSOR guidelines 2008 (change from 10 days)	
Ticlid (ticlopidine)	Continue	Hold for 14 days	
Persantine (dipyramidole)	Continue	Hold for 7 days	
Effient (prasugrel)	Continue	Hold 7 days	
ReoPro (abciximab)	Continue	Hold 48 hours	
Lovenox (enoxaparin)	Continue	Hold LMWH 12-24 hrs as per SIS Guidelines 2nd edition	
Heparin sodium (heparin)	Continue	Unfractionated Heparin (does not need to be held if under 5000 U BID as per SIS Guidelines 2nd Ed)	
Arixtra (fondaparinux)	Continue	Hold 48 hours	
Pradaxa (dabigatran)	Continue	Hold for 7 days	
Xarelto (rivaroxaban)	Continue	Hold 3 days*	
Trental (pentoxifylline)	Continue	Hold 2 days	
Eliquis (apixaban)	Continue	Hold 3 days	

Color key:
Yellow: **Hold medication after reviewing with prescribing physician. (See considerations in yellow discussed following Table A1.1A.)**
*Black box warning for Xarelto:

- Increased risk of thrombotic events and stroke risk when discontinued prior to completion of course.
- Epidural/spinal hematoma risk after neuraxial anesthesia or spinal puncture in anticoagulated patients.

Appendix A2
Steroid Equivalency and Particle Size

Steroid	Dose	Particle Size
Betamethasone Sodium Phosphate and Betamethasone Acetate (6 mg/cc)	1 cc	Vary in size, aggregates, >100 µm, 12 times RBC size
Betamethasone Acetate	1 cc	Unknown
Dexamethasone (4 mg/cc)	1.875 cc	<7.6 µm, no aggregation, <RBC size
Dexamethasone (10 mg/cc)	0.75 cc	<7.6 µm, no aggregation, <RBC size
Triamcinolone (20 mg/cc)	2 cc	.5 µm to >100 µm, aggregates >12 times RBC size
Triamcinolone (40 mg/cc)	1 cc	.5 µm to >100 µm, aggregates >12 times RBC size
Methylprednisolone (40 mg/cc)	1 cc	Most smaller than RBCs, densely packed with few aggregations (propensity to pack densely can form an embolus)
Methylprednisolone (80 mg/cc)	0.5 cc	Most smaller than RBCs, densely packed with few aggregations (propensity to pack densely can form an embolus)

Betamethasone acetate (6 mg/cc) = dexamethasone (7.5 mg/cc) = triamcinolone (40 mg/cc) = methylprednisolone (40 mg/cc).
Medication decisions should be made based on an individual patient and per procedure basis. Recent guideline changes have recommended the use of a preservative-free nonparticulate corticosteroid (i.e., dexamethasone 10 mg/mL) as the sole agent for cervical and thoracic TFESI, and as a first-line therapy for all lumbar transforaminal epidural injections. In certain cases, particulate steroids can be used in the lumbar spine, when limited efficacy has occurred with initial injection of dexamethasone. The goal of this recommendation was to decrease the chances of formation of embolus that could lead to CVA and/or spinal cord infarction, and paralysis secondary to inadvertent intraarterial injection. Of note, this recommendation only applied to the TF approach and no formal recommendations were made for the IL or caudal approaches.

Appendix A3
Drug Dose Reference Guides

Table A3.1 Local Anesthetic Toxicity Dose Reference Guide

Local Anesthetic	Max Dosage (for 70-kg Patient)	Average Dosing (mg/kg)
Bupivacaine 0.25% (2.5 mg/mL)	70 cc (175 mg)	2.5 mg/kg
Bupivacaine 0.25% (2.5 mg/mL) with Epinephrine	90 cc (225 mg)	3.21 mg/kg
Bupivacaine 0.5% (5 mg/mL)	35 cc (175 mg)	2.5 mg/kg
Bupivacaine 0.5% (5 mg/mL) with Epinephrine	45 cc (225 mg)	3.21 mg/kg
Lidocaine 1% (10 mg/mL)	30 cc (300 mg)	4.29 mg/kg
Lidocaine 1% (10 mg/mL) with Epinephrine	50 cc (500 mg)	7.14 mg/kg
Lidocaine 2% (20 mg/mL)	15 cc (300 mg)	4.29 mg/kg
Lidocaine 2% (20 mg/mL) with Epinephrine	25 cc (500 mg)	7.14 mg/kg
Lidocaine 4% (40 mg/mL)	7.5 cc (300 mg)	4.29 mg/kg
Lidocaine 4% (40 mg/mL) with Epinephrine	12.5 cc (500mg)	7.14 mg/kg
Ropivacaine 0.5% (5 mg/mL)	45 cc (225 mg)	3.21 mg/kg
Ropivacaine 0.5% (5 mg/mL) with Epinephrine	45 cc (225 mg)	3.21 mg/kg

The purpose of this table is to guide the practitioner with the maximum amount of local anesthetic dose that can be used when performing an interventional spine procedure.
Recommendations for maximum dosages are given for reference only. A review of the literature did not reveal any evidence for strict dosage measurements. Although it is recommended to be used for an ideal body weight of 70 kg, for patients weighing 70 kg or more, dosing and maximums per procedure can vary from patient to patient due to body habitus.

Table A3.2 Radiocontrast Media Dose Reference Guide

Injection Site	Concentration	Max Dose
Lumbar	Omnipaque 180	17 mL
	Omnipaque 240	12.75 mL
Thoracic or Cervical	Omnipaque 240	12.75 mL
	Omnipaque 300	10.2 mL
Total Columnar	Omnipaque 240	12.75 mL
	Omnipaque 300	10.2 mL
Lumbar or Thoracic	Isovue-M 200	15 mL
Cervical (via lumbar injection)	Isovue-M 200	15 mL
	Isovue-M 300	10 mL
Total Columnar	Isovue-M 300	10 mL

If repeat procedure is required wait for at least 48 hours (5-7 days preferred).
Although the above dosages are suggestions based on credible databases, there are no controlled studies to our knowledge that show any contraindications for use of higher volumes for intrathecal use. There is no evidence or limitation placed on the use of contrast material for epidural use. In regard to myelograms, one study did show no increase in postprocedure complications with the use of higher volumes. The authors would like to note that contrast dosing should be administered with caution for patients who are at risk for contrast-induced nephropathy. These risk factors include age 70 years or older, dehydration (including diuretic use), preexisting renal insufficiency (serum creatinine >1.5 mg/dL), diabetes mellitus, cardiovascular disease, myeloma, hypertension, and hyperuricemia. Although certain techniques can reduce the risk, including dose limitation, hydration methods, monitoring of urine output, and *N*-acetylcysteine administration, we are not aware of any specific consensus on optimal dosing. This should be evaluated on a case-by-case basis in conjunction with the physician treating the patient's kidney disease.
In addition, it should be noted that one could consider the use of gadolinium for patients with allergies to the above based contrasts. However, **the use of intrathecal gadolinium administration is not recommended as there is concern for severe neurologic consequences including encephalopathy, focal seizures, ataxia, and latent tremor.** Based on the known toxicity of intrathecal gadolinium, we advocate that procedures with potential risk of intrathecal penetration (i.e., IL-ESI) should not be performed with gadolinium since the risk of intrathecal gadolinium outweighs the risk of a noncontrast injection.

Appendix A4
Medication Regimen and Recommendations for Radiocontrast Media Administration in Patients with a History of Prior Radiocontrast Media Reaction

- **Anaphylactoid reactions** occur in less than 0.5% of patients who receive nonionic radiocontrast media (RCM)
- **Patients at higher risk:**
  - History of previous anaphylactoid reaction to RCM
  - Those with asthma, cardiovascular disease, and/or currently on beta-blockers
- Patients NOT at higher risk:
  - Sensitivity to seafood and/or iodine does not further increase this risk.
- Patients who experienced previous anaphylactoid reactions to RCM and are receiving contrast should only receive nonionic, iso-osmolar agents (i.e., iodixanol, Vistipaque/Optiprep) and be treated with a premedication regimen such as:
  - Prednisone 50 mg, 13, 7, and 1 hour(s) before the procedure
  - Diphenhydramine 50 mg, 1 hour before the procedure
  - Ephedrine 25 mg or albuterol 4 mg, 1 hour before the procedure
  - May not be favorable in patients with cardiovascular disease
  - Although histamine-2 receptor antagonists are beneficial in the treatment of anaphylaxis, when the addition of histamine-2 receptor antagonists 1 hour before RCM procedures was studied, paradoxically, a modest increase in reaction rate was observed.

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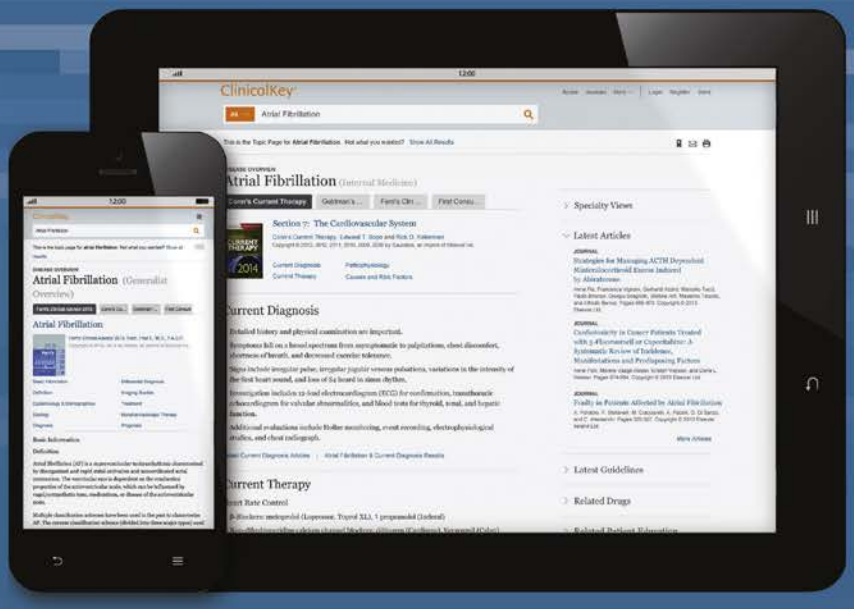

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